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Street Angularity and Patterns in Palembang and Yogyakarta Indonesia

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A B S T R A C T

There is a lack of comparative studies on the street geometry, patterns and angularity of cities, especially those in developing countries such as Indonesia. The problem can be attributed to limited technical knowledge, traditional data collection challenges, and limited data samples. This research used two cities in Indonesia to study differences in street patterns and angularity. They were Palembang—the oldest city, and Yogyakarta—a planned Sultanate city of the country. 14 different study areas, each measuring 2 miles by 2 miles, were selected from each of the cities. These areas represented five different functional categories—historic housing district, unplanned Housing district, planned housing district, historic commercial district, and commercial district. The data acquired for this research included maps from OpenStreetMap (OSM) that were processed using OSMnx, software built on top of Python's Networkx, matplotlib and geopandas libraries—a rich network analytical visualization application. Using OSMnx, the centerline maps of the cities were extracted; which, then, were exported into various file extensions for GIS multi-platform applications to run a spatial analysis. The edge bearing graphs for each of the 14 study areas from each city were obtained from OSMnx. These graphs were compared to see if these areas show similarities and differences in terms of functional categories.
Findings show that Palembang has more variations in street angularity when compared with Yogyakarta areas. Within and between cities, study areas did not show consistent differences based on functional categories. Instead, differences observed in the angularity of streets of these cities appeared to be both historical and cultural in nature.

Keywords: *Street angularity, street pattern, Indonesia*

1. Introduction

This paper examines the street patterns and street angularity of the whole and the parts of two important Indonesian cities in relation to land use. They are Palembang and Yogyakarta. Palembang is the capital of South Sumatera Indonesia. Founded in the 6th century, it is the oldest existing city in Indonesia. It became a colonial port city in the 16th century under the Dutch East-Indian Company. The city has a population of 1,600,000 within an administrative area of 369.22 km^2. Yogyakarta is a Sultanate city that was founded in the 17th century. It was founded in the 17th century. The city has a population of 4,000,000 within an administrative area of 21.59 km^2. These cities were chosen because of the difference in their urban geometry.

The city of Palembang shows a more natural geometric form with a visible geometrical center, while the city of Yogyakarta has a grid-like form. This geometric form can be visible through studying the street centreline that has shaped the city network system.

2. Methods

The study uses street network and road centrelines data from Open Street Map extracted using OSMnx, a python based application. Previously, OSMnx has been used to study urban form, street network, and transportation systems (Boeing 2017). There have been many methods to acquire OpenStreetMap data such as Mapzen, Geofabrik, and API provided by OpenStreetMap itself, but they are not cost-effective and providing simple processes. OpenStreetMap is used because the open-source availability and research have been approving the accuracy of the map and its high quality (Haklay 2010; Barron, Neis, and Zipf 2014; Girres and Touya 2010).

To reconstruct the GIS database for this study, we downloaded an Indonesian GIS database for the administrative zone, providing a digitize shapefile of polygon unit for the ArcGIS platform, from

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http://tanahair.indonesia.go.id/portal-web/login. The GIS database is then combined with the OSMnx street centerlines to analyze the street network properties for this study.

In conducting this research, we took 14 smaller areas – each of two-square miles – to analyze the street properties of each city and to see if there are any ordinaries, similarities or differences amongst the street networks of these areas.

The size of each study area is almost equal to the study areas Kevin Lynch used in *The image of the City* (Lynch 1960). The area generally covers a half-an-hour walking distance and includes a large enough street network. The area also has sufficient complexity for geographers, because it shows the micro and macro scale information of general significance (Rashid 2017).

Each area in the study is chosen to represent one of the following five land use categories:

1. Historic housing district
2. Unplanned Housing district
3. Planned housing district
4. Historic commercial district
5. Commercial district

These five land use categories are commonly found in every city. They showed that different land uses affect their street networks differently. We include both commercial and residential historic districts because most Indonesian cities would have them. Unplanned housing districts are interesting because, even though they grow naturally like the historic districts, they are often developed as squatter settlements on public land. Planned housing districts are selected because they show a shift in Indonesian city development patterns in the Modern era.

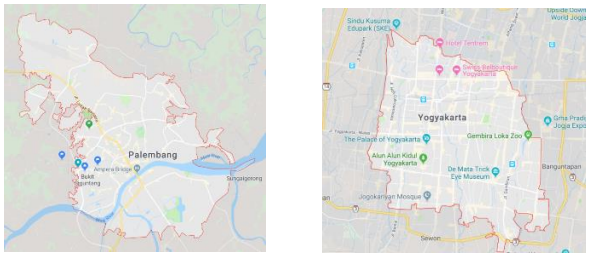


Fig. 1. (a) Map of Palembang; (b) Map of Yogyakarta

2.1. Quantifying order and disorder

To understand the value of the street network, we calculate the order and disorders of each area using the Shannon entropy describing orientations of distribution (Shannon 1948). Shannon Entropy is used to evaluate the value of perfect grid and random angular of the city network, using the method developed by Geoff Boeing (Boeing 2019), where the method is basically calculating the bearings of every edge of the street network in the city into 36 equal-sized bins representing the 360 degrees of street orientation. Each bin represents 10 degrees and the street angular will be stored in the respective angle of each bin.

The calculation is using two-equation, the first equation is the value of the Shannon entropy of every polar histogram graph, where Ho is the Shannon entropy value and n represents the total number of i and *i* indexes the bins, and $P(oi)$ represents the proportion of orientation on the i[th.] Bin:

$$Ho = -\sum_{i=1}^{n} P(oi) log\, eP(oi)$$

The second equation is to normalize the measure of orientation order, φ to indicate where the area stands in a linear spectrum from completely disorder/uniform with the value of closer to zero and to perfectly ordered / grid-like with the value of 1. The value of a maximum entropy $H_{\max}$ would be the value of 3.58 nats, this represents the maximum entropy distribution showing a spectrum of the completely disordered spectrum, while the prefect grid entropy H_g would be the value that is equal to 1.386 nats, creating a perfect grid-like form

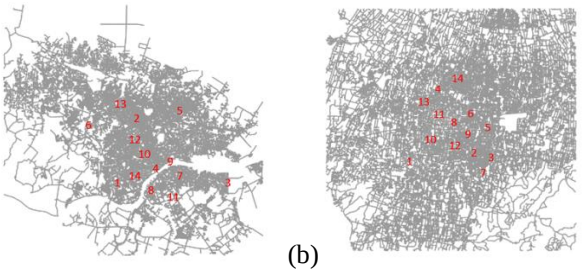
$$\varphi = 1 - \left(\frac{Ho - Hg}{Hmax - Hg}\right)^2$$

The value of 0 on φ will indicate a low order, a perfect disorder and maximum entropy with the uniform of streets in every direction, and a value of 1 on φ indicates a high order creating the idealized four-way grid and minimal possible entropy.

3. Research Findings

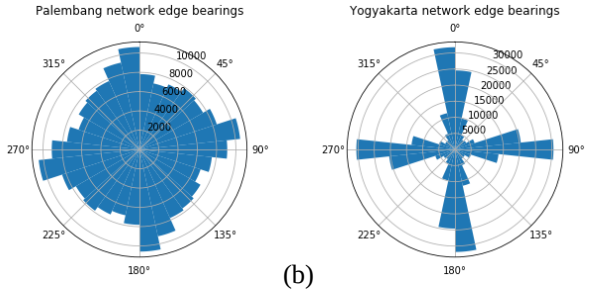
The research data collected from the two cities of Palembang and Yogyakarta in Indonesia, using a sample area of 676km2 or 2.6 kilometers x 2.6 kilometers to collect comparable results. This dataset shows that Yogyakarta is a more dense city compared to Palembang. The total length of the Yogyakarta street network is 4,670,180 meters while Palembang has a lower density, showing the total length of the street network with 3,659,940 meters. The main differences that we could observe from these two cities are that Palembang is a structured city that grows more natural and organic from a center located near the Musi River, while Yogyakarta is a city with order and shows a grid-like pattern throughout the city.

In Comparison, the Palembang and Yogyakarta show major differences. Palembang is showing a circular network orientation, while Yogyakarta is showing a strong grid network orientation.



(a) (b)

Fig. 2. (a) Palembang 14 study area; (b) Yogyakarta 14 study area.



(a) (b)

Fig. 3. (a) Palembang polar histogram; (b) Yogyakarta polar histogram.

3.1. Palembang Street Patterns

The 14 districts of two-square miles of Palembang in alphabetical order, respectively is Bukit Siguntang-Historic housing district, Kebun Bunga-Unplanned housing district, Komperta Plaju-planned housing district, Masjid Agung-Historic commercial district, Perumnas Kenten-Planned housing district, Perumnas Talang Kelapa-Planned housing district, Seberang 10-14 Ulu-Unplanned housing district, Seberang 5 Ulu-Unplanned housing district, Segaran-Historic commercial district, Simpang Charitas-Commercial area, Simpang Jakabaring-Commercial area, Simpang Polda-Commercial area, Sukabangun-Unplanned housing district, and Talang Semut-Historic housing district.

The research findings in these areas show a mixture of results, combining multi-oriented and disperse street network and grid-like street network. These findings confirm that the relationship between the whole and parts of the city is not consistent.

These are the following 14 two square areas map of street angularity diagram and area description of the Palembang study districts.

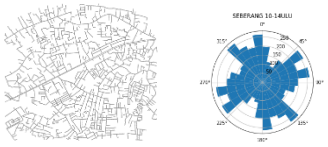
Table 1. Palembang 14 two-square-miles area of study

Area Description	Area Map	Street Angularity
1 Bukit Siguntang An ancient burial site from the *Sriwijaya* empire and believed to contain the ancient burial of the ruler of Sriwijaya. It became the historic housing district and housing for native dwellers		
2 Kebun Bunga An unplanned housing district, the *Kebun Bunga* area was developed in the 90s. It comprises between sprawl with small developer housing. This district was generally used as housing because of the hilly topography and resistant from flooding of Palembang		
3 Plaju Once known as the city of Oil, the *Plaju* area was once started operating in 1904. The *Plaju* district is a combination between an oil plant and a planned housing complex for a foreign worker for the Oil company. Now the oil plant is still working under the Government oil company *Pertamina* and the housing serves for local oil workers		
4 Masjid Agung The center of Palembang or known as "*titik nol*" it is basically the center of historic commercial of Palembang. Once evolve from the colonial port area, the district now consists of commercial grids, central mosque and also riverfront of Palembang.		
5 Perumnas Kenten A planned housing area developed in the 90s during the rise of political and economic development of Indonesian cities, today the *perumnas* Kenten area is one of the dense and evolving parts of housing and commercial areas in Palembang. This area is quickly growing with new commercial properties.		
6 Perumnas Talang Kelapa A modern planned housing area, developed in 2010, this area is set by a large corporate national developer to be a new housing area in Palembang. The developer acquired 200 Ha of land to be		

developed for new housing, business and commercial center of Palembang.

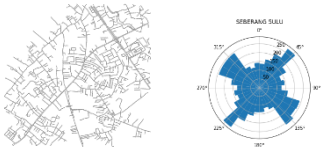
7 Seberang 10-14 Ulu

A traditional unplanned housing quarters, this area is a historic district that has been evolving with the city of Palembang's evolution. This area is also known as "*kampung Arab*" or the village of the Arabs with the majority of settlers are descendants and families of earlier Arab traders.



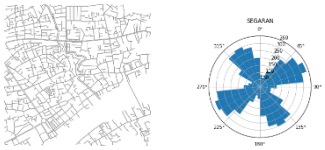
8 Seberang 5 Ulu

A traditional unplanned housing quarters. This area is the settlement of native Palembang and Chinese traders, with unique boat houses because of the location of the houses that is the majority on top of the riparian area of the Musi river in Palembang.



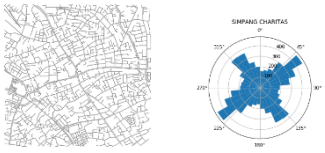
9 Segaran

This was the central traditional and historical commercial area with its location just adjacent to the *Masjid Agung* area. It is the location of warehouses and boat docks, a place for trade of goods in the city of Palembang



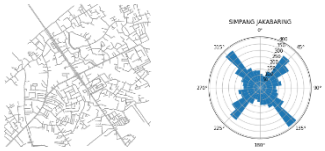
10 Simpang Charitas

One of the busiest intersections in Palembang. This area was first an important center of the military hospital, now it has transformed to be a commercial grid that is filled with a mixture of shophouses, commercial centers, offices and also the city hospital.



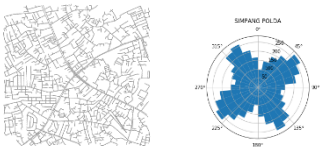
11 Simpang Jakabaring

One of the most important intersections in the Ulu area of Palembang, connecting the Plaju and Seberang Ulu and also connect to the national sports facilities in Jakabaring. This area has transformed into a mixture of commercial and educational facilities.



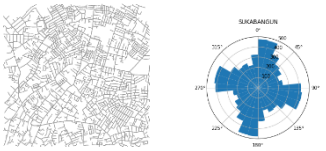
12 Simpang Polda

This is also an important intersection in Palembang, connecting the outer ring road of the city, this area is a mixture of a commercial area, education and government offices and also with unplanned housing in the outer loop of the street



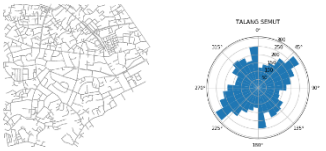
13 Sukabangun

An unplanned housing area on the upper hill topography of Palembang, this location is a favor to native dwellers because it is considered to be safer from flooding. The area has evolved to be a dense housing area and also now emerges small retail commercial kiosks



14 Talang Semut

A colonial planned housing that was built for the settlement of the Dutch settlers in Palembang. This location is now preserved with colonial buildings and with green urban spaces and parks.



3.2. Yogyakarta Street Patterns

The 14 districts of two-square-mile area of Yogyakarta in an alphabetical order, respectively is Bantul-Unplanned housing district, Dagaran-Unplanned housing district, Jaranan-Unplanned housing district, Jogja City mall-Commercial area, JogjaExpo-Commercial area, Kotabaru-Planned housing district, Kotagede-Planned housing development, Malioboro-Historic district, Pakualaman-Historic district, Patangpuluhan-Planned housing district, Stasiun Jogja-Historic district, Tegalrejo-Commercial area and UGM-Planned housing district.

The research findings in Yogyakarta shows a consistent relationship between the street angularity of the whole city with the smaller two-square-mile parts of the city. Both of the whole and parts of the city have shown a grid-like street network with minor differences in the street angle.

3.3. Neighborhood Street Patterns

From the analyzed data of the two-square-mile area, we describe the ordinaries, similarities, and differences using geometric measures of the street centerline maps. The resulting area shows the total length of the street, the mean length of the street, the maximum length of the street, the

total number of the street segment and the total intersection shown on **table 2** and **table 3**.

The most significant value in the total length of the street in Palembang is *Perumnas Kenten*, a planned housing district, created in the 1970s with the entire length of 144,341 meters or 144 km of the street network in a two-square-mile of area. This area is showing the density of function and use of the area. The area was intended as a housing area, but the function changed into a mixture of housing and commercial space. Perumnas kenten also show the highest number of the street segment with 2593 street segments and a total of 1553 intersections.

The other district that is showing density in Palembang is the unplanned housing district and the commercial areas, while the unplanned traditional district is showing less density than the other district. This unplanned housing district is located in the Riparian area of the Musi River, the main river that is dividing Palembang city into two sections. The linear density is lower with the minimum value of the total length of 88,231 meters or 88 km and the entire intersection of 704 intersections. The condition of this unplanned district also has geographical features of the Musi River, where this condition is creating a deficiency in development in the district.

The lowest value of the total street length in Palembang on this research is *Komperta Plaju* that has a total length of 63,020 meters or 63 km. It is one of the earliest planned housing districts in Palembang, created in the late 50s provided as a housing location combined with the Oil refinery in the *Plaju* area. This location is pretty much contained and does not have many changes since its establishment and that the place is still maintained by the government oil company called *Pertamina*.

The most significant value in the total length of the street in Yogyakarta is called the *Kotagede*, a planned housing district with the value of the total length of 123,734 meters or 123 km. The linear density of the area is also consistent with the highest number of 1938 street segments and 1116 total intersections; this number is showing the density properties in the two-square-mile of the *Kotagede* area.

The other district that is showing similar linear density in Yogyakarta is the unplanned housing district and commercial area with the total length of street respectively of 109,374 meters and 103, 929 meter, while other commercial and unplanned housing districts are showing various result but the overall regression is showing a similar pattern of value with case by case differences.

The histograms showing the comparison of distributions between two cities of Palembang and Yogyakarta shows that the total number of intersections including dead ends, 2,3, and 4 ways intersections on the area of a two-square-mile has a mixture of results. In Palembang, the highest number of total intersections in the historic district is 1553 points while the lowest quantity of intersections in the planned housing district is 359 points with a mean number of intersections of 948 points. While in Yogyakarta the highest number of total intersections is in the planned housing district is 1116 points, while the lowest number of intersections in the unplanned housing district with 430 points with a mean number of intersections of 662. From this comparison, we understand better than the city with a more ordered street pattern tend to have less and a lower number of intersections while the city with a more structured street network has the highest number of intersections. **Fig.5**

In a comparison of the five area categories between the two cities also shows that Palembang as the more natural city has a higher number of intersections while Yogyakarta as the more ordered city shows a lower number on intersections. The similarities shown between the two cities is on the unplanned housing district and commercial district, where the variations on those categories are not as high as other categories.

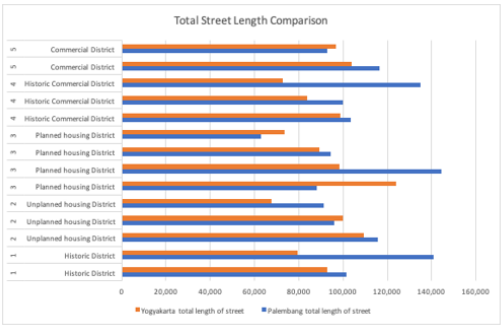


Fig. 4. Total street length comparison between Yogyakarta and Palembang.

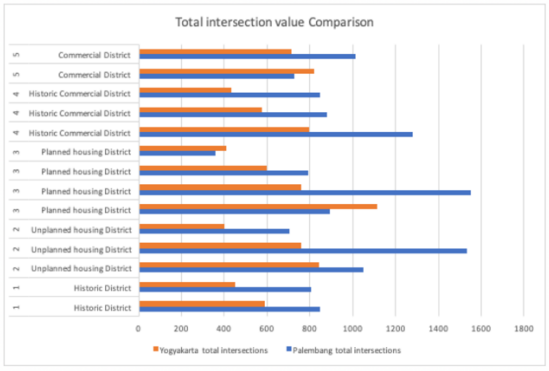


Fig. 5. Total intersection value comparison.

Table 2. Palembang Grid to Circular pattern value

STREET NETWORK PROPERTIES OF PALEMBANG: DATA ANALYSIS IN METERS

NO	AREA	type	code	total length of street	mean length of street (meter)	maximum length of street (meter)	total number of street segment	Total number of dead Ends	intersection 2	intersection 3	intersection 4	total intersections
1	Bukit Siguntang	historic housing district	1	101,434	66.34	500.35	1529	448	4	774	70	848
2	Kebun Bunga	unplanned housing district	2	115,583	62.57	454.03	1847	439	2	941	107	1050
3	komperta pelaju	planned housing district	3	***63,020***	**102.8**	1017.42	***613***	***69***	***0***	***281***	78	***359***
4	masjid agung	CBD historic	4	99,998	67.65	**1269.44**	1478	342	**14**	744	87	845
5	Perumnas Kenten	planned housing development	3	**144,341**	55.66	409.71	**2593**	387	1	**1411**	**141**	**1553**
6	Perumnas Talang Kelapa	modern planned	3	94,491	64.19	862.72	1472	164	3	786	104	893
7	seberang 10-14 ulu	traditional unplanned	1	95,762	65.41	411.86	1464	449	4	736	65	805
8	seberang 5 ulu	traditional unplanned native	2	88,231	69.2	477.73	1275	401	3	661	40	704
9	Segaran	historic commercial district	4	103,492	66.64	1134.11	1553	405	12	787	78	877
10	Simpang Charitas	commercial area	4	134,972	59.77	494.24	2258	585	12	1158	108	1278
11	simpang jakabaring	commercial area	5	92,899	71.18	1147.23	1305	400	4	684	37	725
12	Simpang Polda	commercial area	5	116,456	64.59	550.25	1803	520	5	948	***58***	1011
13	Sukabangun	unplanned housing district	2	140,814	***52.09***	***344.76***	2703	**652**	***0***	1374	158	1532
14	Talang Semut	historic housing district	2	91,072	65.66	396.94	1387	328	4	718	70	792

BOLD = highest Number

Italic = lowest number

Table 3. Palembang Grid to Circular pattern value

STREET NETWORK PROPERTIES OF YOGYAKARTA: DATA ANALYSIS IN METERS

NO	AREA	type	code	total length of street	mean length of street (meter)	maximum length of street (meter)	total number of street segment	Total number of dead Ends	intersection 2	intersection 3	intersection 4	total intersections
1	Bantul	unplanned housing developmen	2	***67,638***	97.6	531.7	***693***	144	4	***354***	***43***	***401***
2	Dagaran	unplanned housing developmen	2	109,374	78.51	746.6	1393	201	5	746	91	842
3	Jaranan	unplanned housing developmen	2	99,687	77.63	455.92	1934	212	1	686	74	761
4	JogjaCityMall	commercial area	5	96,908	82.47	1135	1175	133	5	634	76	715
5	Jogja Expo	commercial area	5	103,929	75.75	541.4	1372	201	2	*729*	88	819
6	Kotabaru	planned housing development	3	89,115	88.4	1030	1008	155	**12**	510	76	598
7	Kotagede	planned housing development	3	**123,734**	***63.84***	**1349**	**1938**	**421**	4	**1005**	**107**	**1116**
8	Malioboro	CBD historic	4	72,749	97.65	652.6	***745***	150	4	374	52	430
9	Pakualaman	historic district	1	92,679	91.76	525.4	1010	127	4	484	103	591
10	Patangpuluhan	planned housing development	3	73,435	**105.05**	652.6	699	114	***0***	362	49	411
11	Stasiun Jogja	CBD historic	4	83,592	84.01	969.5	995	209	10	506	60	576
12	Tamansari	historic district	1	79,340	103.84	652.6	764	***113***	**7**	381	64	452
13	Tegalrejo	commercial area	5	98,854	72.79	***451.8***	1358	241	5	705	87	797
14	UGM	planned housing development	3	98,374	78.51	508	1253	162	8	677	74	759

BOLD = highest Number

Italic = lowest number

4. Discussion

Polar histograms on the city of Palembang from 14 samples area sorted by descending from the most to least grid-like or from the greatest to the least value of entropy showing the area or part of the city that has more order in the street network in descending with the part of the city that has less order **Fig.6**. From the street angularity, we could see that the city of Palembang in a whole is a city without a grid-like pattern on the city, but in the parts of the city especially in the planned housing district, we could argue that most of the planned housing district applied a grid pattern but with different angular of street network. The area with the most order street network is an area that is more contained than any other, other planned housing district also show the order in the grid pattern street network but with a different angularity.

The street pattern in Palembang shows a mixture of the grid and uniform pattern in the city, and the angularity of the street network is showing a large number of directions. The planned housing district shows a consistent grid pattern, with *komperta Pelaju* as one of the old planned housing as the measured orientation order of 0.889 and *perumnas Talang Kelapa* with the measured orientation order of 0.534, a number closer to 1 or the perfect grid. **Table 4**

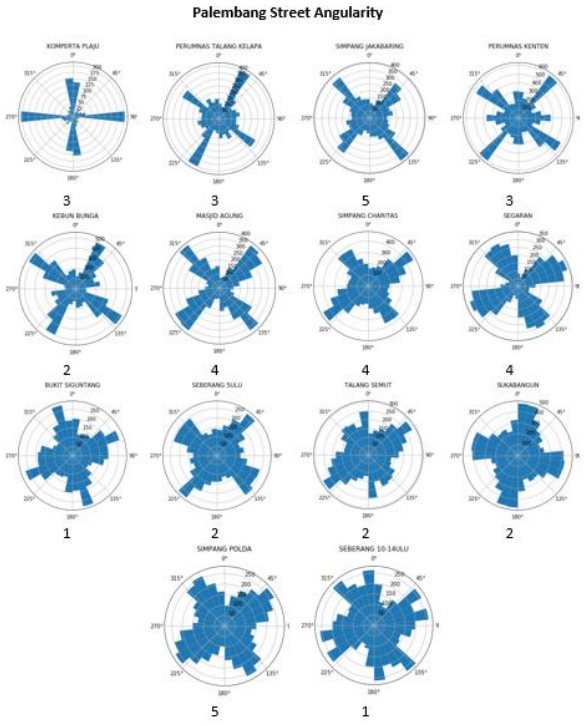


Fig. 6. Palembang 14 area of study polar histogram.

Table 4. Palembang Grid to Circular pattern value

categories	area	Ho	φ
3	komperta pelaju	2.120	0.889
3	Perumnas T Kelapa	2.887	0.534
4	masjid agung	3.135	0.367
2	Kebun Bunga	3.136	0.366
3	Perumnas Kenten	3.226	0.299
5	simpang jakabaring	3.230	0.296
4	Segaran	3.420	0.143
4	Simpang Charitas	3.420	0.143
2	seberang 5 ulu	3.506	0.070
1	seberang 10-14 ulu	3.533	0.046
1	Bukit Siguntang	3.534	0.045
2	Talang Semut	3.546	0.034
5	Simpang Polda	3.549	0.032
2	Sukabangun	3.552	0.029

The polar histogram on the city of Yogyakarta from 14 samples of a two-squared mile in descending order from the most grid-like order to the least order shows subtle differences in **Fig.7**. From the street angularities, we could see that the city of Yogyakarta as a whole has a grid-like pattern and order. We could see there are also differences in the street length, angularity, and diversity in the polar histogram. This result shows that the historic district of *Tamansari* has the most order and shows the longer length of the street connecting the north and south area but shows less length of street on the east to west area. While the other polar histogram shows a mixture of orders from the commercial area, planned housing and also the unplanned housing with the consistency characteristic of the grid-like street network.

The street pattern in Yogyakarta shows a uniform of the grid pattern with slight differences in the street angularity. The consistency of the grid pattern heading north and south direction is due to the fact that the city of Yogyakarta established a metaphysical respect to the mount Merapi in the north and south sea (Haryono 2015). The measured orientation grid of Yogyakarta shows a value of 0.9996 with a lower value of 0.7810. The entropy value is a clear indication that Yogyakarta has a consistent grid pattern through-out the city. **Table 5**

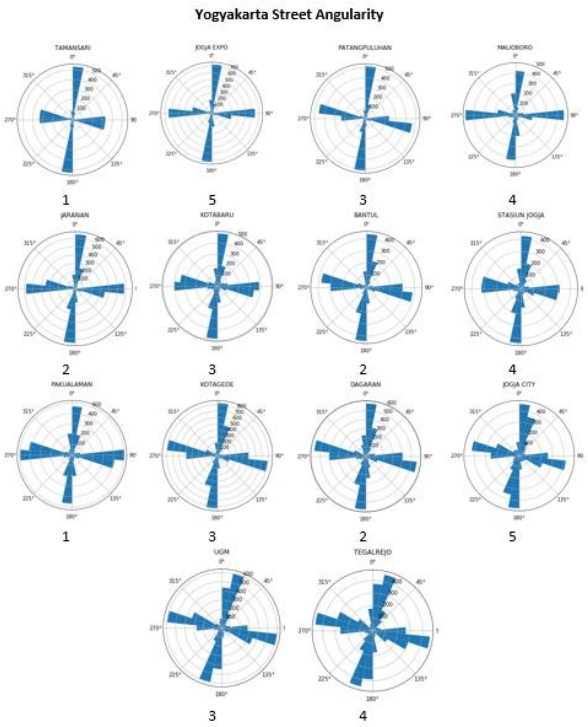


Fig. 7. Yogyakarta 14 area of study polar histogram.

Table 5. Yogyakarta Grid to Circular pattern value

categories	area	Ho	φ
5	Jogja Expo	1.432	0.9996
1	Tamansari	1.285	0.9979
3	Patangpuluhan	1.500	0.9973
4	Malioboro	1.622	0.9885
2	Jaranan	1.679	0.9822
2	Bantul	1.840	0.9573
3	Kotagede	1.903	0.9447
1	Kotabaru	1.959	0.9320
3	Pakualaman	1.972	0.9290
4	UGM	2.016	0.9179
2	Stasiun Jogja	2.144	0.8811
4	Dagaran	2.209	0.8599
3	Tegalrejo	2.317	0.8207
5	JogjaCityMall	2.415	0.7810

5. Conclusions

The study showed the similarities and differences between the whole and parts of Palembang and Yogyakarta, not only the two cities have differences in geometry and angularity for the whole city, but the results show that the two-square-mile area has similarities in pattern and street angularity. The result shows a similarity in density whereas the whole density of the city is different due to the existing neighboring city in Yogyakarta, but the density of the two-square-mile area shows a consistency value between 60 km to 144 km of total street length. The pattern shown between the two cities indicates that there is an adjustment of how the two cities react to the need for commercial spaces, especially on the micro commercial that visibly exists in Indonesian cities. This pattern language is an essential function in neighborhoods to have residential areas combined with commercial activity (Alexander 1977). Further research and comparison between Indonesian cities are needed to have a better understanding of the pattern and geometry of Indonesian cities.

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