Conference Paper

Housing Morphology and Connectivity Quality in Periphery of Bandung City: Space Syntax Analysis

Try Ramadhan[1], Lukman Hendra Septian[2], and Allis Nurdini[3]

[1]Master Student in Architecture, Green Building Research Center, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia
[2]Master Student in Architecture, Housing, and Settlement Research Group, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Indonesia
[3]Housing and Settlement Research Group, School of Architecture, Planning and Policy Development, Research Centre for Infrastructure and Regional Development, Institut Teknologi Bandung, Indonesia

Abstract

The complexity that occurs in the city is determined by its diversity and intensity of inhabitant activity. The connectivity system becomes an essential factor to accommodate these lively activities, especially connectivity of the housing area to the working area and public facilities. Periphery area of some metropolitan city including Bandung City has been growing fast, which is influenced by the intense need for housing accommodation, as well as accommodation of educational and industrial sectors. The East Peri-Urban of Bandung City in this decade became a more high density, especially along the primary arterial road that connects the Western and Eastern area of Bandung. This study aims to analyze the morphology of housing development and its connectivity including road networks that located in three area of the East Bandung from 2007 to 2017: Jatihandap, Pasir Impun, and Cijambe corridors. Space Syntax analysis is conducted to perform this morphology study. Data collected by direct observation and secondary sources review that related to the development of housing settlement in the area. It is concluded that the development of housing morphology in the peri-urban area of Bandung within ten years is growing intensively. There is some dis-integration pattern of road connectivity in the case study, which tends to be isolated or can be called as "big housing pocket". The connectivity or permeability of the housing area in the peri-urban city is urgently needed to intervene, in order to reduce isolated settlement pattern and daily heavy traffic.

Keywords: housing, morphology, periphery, road connectivity, space syntax.

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Try Ramadhan

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1. Housing in Periphery Bandung and Space Syntax Analysis: Introduction

Bandung with a total of 2.5 million people is one of three high-density cities in Indonesia after Jakarta and Surabaya [1]. Bandung City with a total area of 168 km2 became the center of political, economic, and social activities in Indonesia. The development of the commercial, educational and industrial sectors in Bandung is very beneficial supported by economic growth, population increase, and urban expansion [2].

Along with the increase of Bandung City population and its activity, impact on the emergence and development of many housing settlements. Dense spaces in the city center today lead the development shift of housing settlements into a periphery of the city or outer city boundary. Limited urban land has resulted in peripheral development dynamically [3], which the most visible is the physical changes and heavy daily traffic. Morphology study conducted to identify the growth condition of housing in the city peripheral.

Research related to housing morphology at urban periphery had been conducted by Putri, Rahayu, & Putri [3] primarily in Surakarta. This study summarises about phenomena of mixed land use patterns, spinal road network patterns, different density, and various building patterns. It is also identified the form of octopus morphology in the peripheral of Surakarta as the characteristics of morphological components.

The selected tool to identify the morphology pattern of settlements in the periphery of Bandung City is space syntax analysis, especially the connectivity quality that are formed in the development area.Space syntax is a method developed in the late 1970s and early 1980s at Bartlett School of Architecture and Planning, University College London by Bill Hiller and Julienne Hanson research teams to observe urban spaces [4]. Onder & Gigi [4] said that by this method, we could perceive the urban system about syntactic systems, such as symmetry-asymmetry, distribution, integration-segregation, determination of control values, integration features and morphology.

Research related to space syntax develops in various things; for example, Mohamed [5] in his study analyzed the comparisons of two informal areas that represent the typology of urban housing in Cairo. In his research, Mohamed uses space syntax analysis to examine the spatial configuration of both settlements. The result is that commercial roads and main roads have higher ratios than non-commercial roads, such as alleys and dead ends. The Önder & Gigi [4] study uses space syntax analysis as an evaluation before and after the design intervention. Choi, Kim, Oh, & Kim [6] used space syntax theory in his research to develop a strategic methodology of street lighting design based on the space syntax analysis of the movement rate of pedestrians and related to the illuminance value of a district in Korea. Research Li, Xiao, Ye, Xu, & Law [7], space syntax analysis is used to describe the tourist space in the historic area of Gulangyu Island. With space syntax analysis, we can describe the general morphological structure of road network integration and the effect of road network integration on tourist preferences.

Kim & Sohn [8] study on the relationship between urban road configuration and land use for office buildings. The result of this research is that the density of land use is influenced by road configuration.

This study aims to identify the development of housing morphology and connectivity quality in the context of periphery development of Bandung City. Three locations at Eastern periphery of Bandung City is selected as case studies: Jatihandap, Pasir Impun, and Cijambe. The three areas represent the common type corridor that stimulated built environment development in the Eastern of Bandung City.

2. Case Study

The three areas of the case study are a major residential area that emerges and grow in the periphery of the city and connected to the first artery road: AH Nasution Street (ST). AH Nasution ST. is an arterial road with high-density traffic to connect Bandung City with another city like Sumedang City, and it also has to serve the local inhabitants heavy traffic from and into several house estates and kampong in Eastern Bandung. This road is also represented as the public entrance and exit of the Bandung City, beside the toll road.

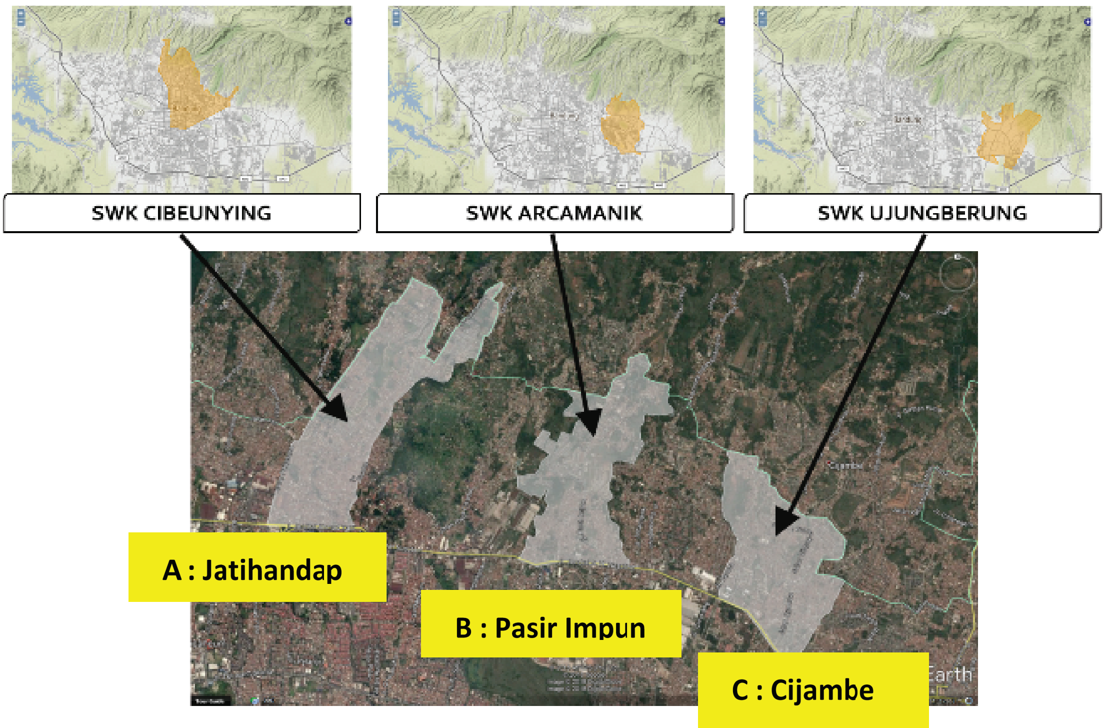

Figure 1: Three settlements in the primary arterial road area of Bandung as case studies (Source : Modified by author from google map).

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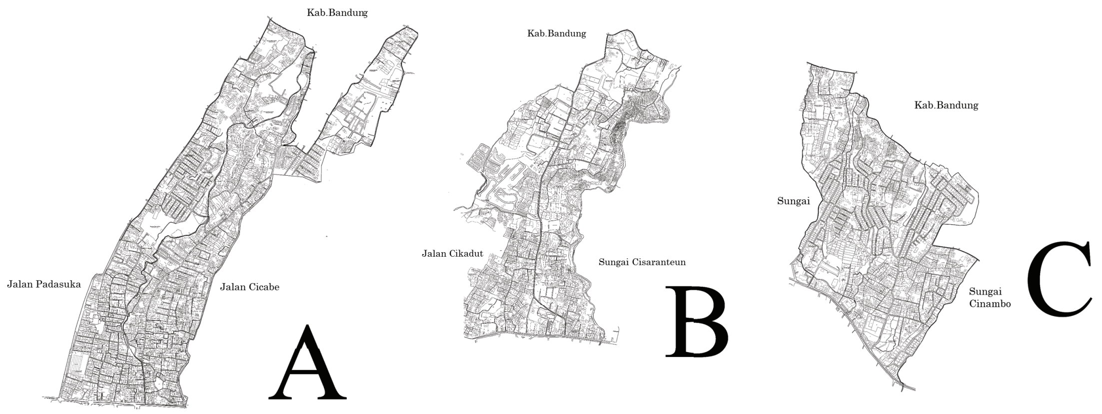

Figure 2: Housing settlement morphology in the corridor of Jatihandap (A); Pasir Impun (B); Cijambe (C) (Source : Modified by author from city map).

Selected case studies are located on the Eastern Bandung City: Jatihandap, Pasir Impun, and Cijambe area. Although connected in the similar arterial road these three cases are situated in different Sub City Area or called as SWK. Jatihandap area is located at SWK Cibeunying, Pasir Impun area is situated in SWK Arcamanik, while Cijambe area is located at SWK Ujungberung (Figure 1). The selected cases are also directly adjacent to Bandung Regency area (see Figure 2).

3. Method

This research is categorized as explanatory research [9]. The study area that located at three corridors in the periphery area of Bandung City: Jatihandap, Pasir Impun, and Cijambe are selected as case studies to be identified their housing morphology and connectivity quality from 2007 and 2017. The research was conducted in three stages; the first stage: identify the settlement morphology changes of the three settlements. The next step is to identify road connectivity in the three settlements. The first and second stage is conducted through the space syntax study. The final step is to confirm the space syntax analysis (which uses digital software) with direct field observations and documentation.

Data collected through primary and secondary sources. Primary data is carried out through field observations to determine the characteristics of the road (width and site contours) and document the exact conditions in the field related to the results of the previous analysis while secondary data was associated to space syntax and settlement morphology. The secondary data used was taken from SWK Map Bandung (2011) for space syntax analysis and google earth satellite imagery from 2007 - 2017 for morphological analysis. Figure and ground model in black and white color was used to differentiate the built and undeveloped areas. Axial analysis of space syntax was used to study the road network connectivity in all three settlements. The analysis was performed using DepthmapsX software (Multi-Platform Spatial Network Analysis Software).

4. Space Syntax Analysis

Space is understood as a void (street, box, room, garden, etc.). The void is defined by a barrier that may restrict access and block the view (such as walls, fences, furniture, partitions, and other obstacles). The building consists of a series of spaces; each room has at least one connection to another area. This structural property consisting of space and connections may have embedded social significance that has implications for the overall behavior of human habitats [10]. It is stated that the same description also applies to the urban scale. A city is a building aggregate that is united by a network of space flowing between blocks. This network connects a set of road spaces that form separate structures.

The structure is the optimal result of the shortest path from all origin to all destinations in the spatial system. That's what brings together everything. It has an architecture, and by this means a specific geometry and a specific topology, that is, a particular connection pattern. The topology and geometric analysis of the urban grid using the DepthmapsX software helps to understand the urban space configuration and the potential impact on social behavior and economic activity [10].

Analysis began with the preparation of the axial map. The axial map of the open space structure of the settlement will be the smallest set of straight lines that pass through each convex space and make all axial networks, and a convex would be the smallest set of illicit rooms covering the system [10]. Once the axial map was complete, the data to be observed was entered into the program that executes the required calculations. The result separates separate and integrated areas. The latter identified as the core of the settlement (integrated core) and consists of roads with the highest probability of passersby.

Road network pattern is a collection of various interconnected road networks. The road network eventually forms a model or pattern. Six road network patterns are generally formed and identified in the context of cities such as grid patterns, radials, radial rings, spinal, hexagonal, and delta [11]. The other morphological component is the pattern-related building and its density. In general, there are three patterns of buildings that form within an area among different patterns homogeneous, heterogeneous, and

Figure 3: Sample of space syntax analysis: The higher value of the angle selection is given in red, and the lower value is blue [9].

spread [12]. Also, building density is divided into three, among others, high, medium and low density seen from Building Coverage Ratio (BCR) [13]. The combination of the three characteristics of the components that ultimately can form the morphology of an area (Table 1).

Table 1: Characteristics of the morphological form [3].

Morphology	**Road Network Patterns**	**Building (Density and Pattern)**
Concentric	Spinal concentric radial, radial ring	High density at the center
Elongated	Grid, spinal	High density along the road, heterogeneous
Octopus	Radial concentric, radial rings, spinal	High density at the center and along the way, heterogeneous
No patterned	No patterned	Medium density, heterogeneous
Linearly sweet	Grid, spinal	Intermittent density, heterogeneous
Satellite	Radial concentric, radial rings, spinal	High density at the center of the region, heterogeneous
Split	No patterned	Medium density

Connectivity measures the configuration of space only in spaces that are directly connected space in a configuration [14]. Connectivity estimates how many paths are connected to the observed track. Connectivity is used to determine the level of interaction of each space to the spaces that are near the area. The primary function of the connectivity value is to measure the level of intelligibility. Calculates its connectivity value by summing up all the area directly connected to the observation space. Integration is measuring the configuration of each origin space to another area in a system. In general, this calculates how close the observation space is to all other areas and can be seen as a measure of relative asymmetry (or relative depth) [14]. Integration measures how integrated a (or central) road to an Integration network can be thought of as representing a potential destination — the more space connected with the observation room, the higher the value of integration. Choice measures how likely a path passes from space to all other spaces throughout the system or within a predetermined range (radius) [15]. Option measures how important a road is as a road or a high potential for movement. All three kinds of analysis is based on metric distance [16].

5. Result and Discussion

This section explains the relationship between housing settlement morphology and the connectivity that was analyzed through space syntax integration analysis. High integration values indicate the high intensity of interaction in residential space (roads). High concentration of road use also shows to be developed into public facilities. The following is the elaboration of the three case studies on morphological and connectivity linkages. At this stage will discuss the analysis of connectivity case study using space syntax related connectivity, integration, and choice.

Case 1: Jatihandap

The development of this region is very related to its morphological forms, road network patterns, density, and building patterns. Based on the settlement map from 2007 to 2017 (Figure 4), this settlement has been developing into high density. The elongated morphology has the characteristics of settlements that develop in the form of long and follow the pattern of the spinal pattern road network (Table 2).

Jatihandap has a minimum connectivity value of 1, with an average of 3,07818. In the other side, the maximum amount is more than five times the average value, which is

Table 2: Characteristic of morphological form in Jatihandap area (author's analysis).

Morphological form	Extend along Jatihandap corridor
Road network pattern	Spinal road
Building density and pattern	High density along the main road, heterogeneous

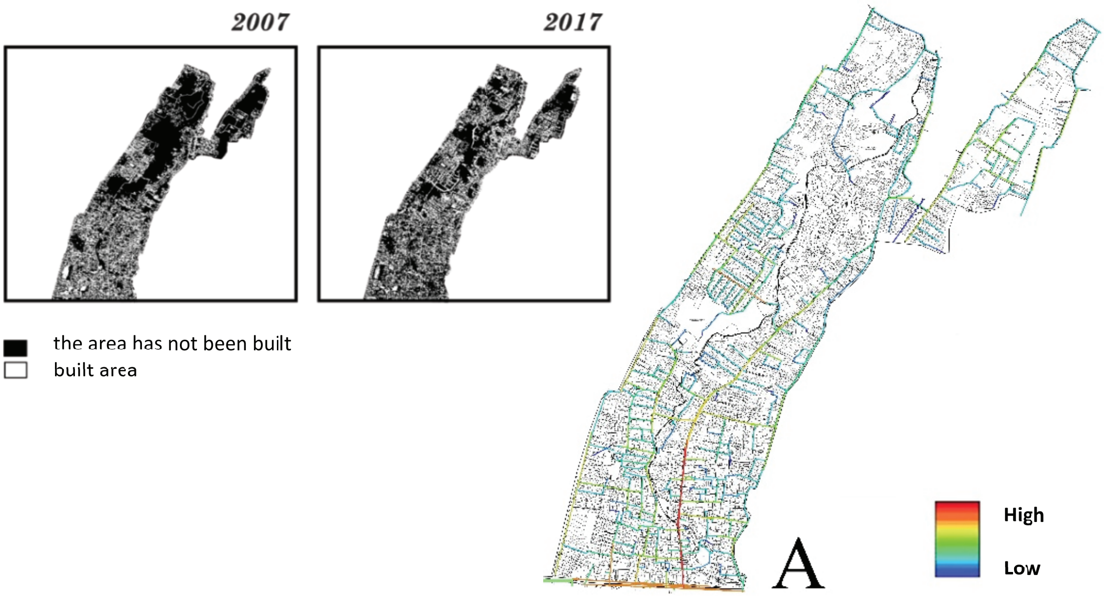

Figure 4: Morphology and road integrity map of space syntax analysis results in Jatihandap area (Source : author's analysis).

16 (Table 3). The highest connectivity value is located at the base of the road corridor. Jatihandap has a minimum Integration value of 0.210897 in dark blue and a maximum amount of 4.80833 in red. Jatihandap has an average integration value of 1,71595 (Table 3). The highest integration value was located at the base of the road corridor, and towards the AH Nasution arterial road (Figure 4) The highest amount of choice R2 reaches 133 (Table 3) which is at the base of the road corridor, the same as integration. This indicates that the road has a high movement intensity. This space becomes a space that can be developed for economic or public activities.

From this space syntax analysis, it can be interpreted that the high value of integration, connectivity, and choice at the base of Jatihandap road represents the high level of importance. The core of the road not only has a lot of direct road network and overall configuration but also becomes a potential destination and a very high movement in the region. As a result, AH Nasution Street has very high integrity. Compared to the two other road cases, Jatihandap corridor has the highest maximum for integration and choice in R2 value (4.80833 and 133), see Table 3,5 and 7. This shows that access to settlements on Jatihandap corridor and surrounding areas indicate "having more complex integration" compared to other case studies. This is influenced by the morphological character of the settlement in the region. It could be concluded that the Jatihandap corridor nowadays has a very high duty to collect and distribute the inhabitants flow out and in the area. It can be understood that the most massive traffic jam would happen daily in the intersection of Jatihandap corridor and AH Nasution Street.

Table 3: Integration, connectivity, choice in Jatihandap road (author's analysis).

Attribute	Minimum	Average	Maximum
Choice R2	0	5.57329	133
Choice [Norm] R2	0	0.16847	0.666667
Connectivity	1	3.07818	16
Integration [HH] R2	0.210897	1.71595	4.80833
Line Length	2.14479	64.4984	650.425
Mean Depth R2	1.25	1.60749	1.88889
Node Count R2	3	9.65147	45
RA R2	0.0295983	0.244286	1
Step Depth	0	11.456	35
Total Depth R2	3	14.2248	72

According to integration analysis, Jatihandap area has the irregular residential character of its morphology. High and heterogeneous building density levels on each segment make the Jatihandap highway has high connectivity, integration, and choice R2 among others. This indicates that Jatihandap area has a road network (space) with high activity intensity. This road is located in the base of Jatihandap road which is located close to the main arterial road of Bandung, AH. Nasution Street. Red roads show the potential of the density of activity at certain hours that occur at one time. Figure 5 shows the Jatihandap road situation, along Jatihandap road, there are a lot of stalls, high density, and alley as well. Also, there were also frequent traffic jams at the intersection of AH. Nasution Street and Jatihandap corridor.

Figure 5: Jatihandap road situation. (A & B) Along Jatihandap road, there are a lot of stalls, high density, and alley as well. (C & D) traffic congestion at the T-junction of PPH Mustofa and Jatihandap road (author's analysis).

Case 2: Pasir Impun

Based on morphology (Table 4 and Figure 6), Pasir Impun tends to be linearly shaped in 2007. However, they began to develop intensively in 2017. The linear morphological form has the characteristics of settlements that promote linearly but grow apart at the base and end of the region. This form follows the spinal pattern of intermittent road networks.

Table 4: Characteristic of morphological form in Pasir Impun area (author's analysis).

Morphological form	Linear *with node* – base and end of Pasir Impun
Road network pattern	Spinal road
Building density and pattern	Medium density, heterogeneous

The residential area of Pasir Impun (see Figure 5) has a linearly morphological shape with intermittent and heterogeneous density, as well as a forked road network. The high integrase level in the area lies in the central corridor of Pasir Impun road and away from PPH Mustafa road. It can be concluded that the road has a high usage intensity.

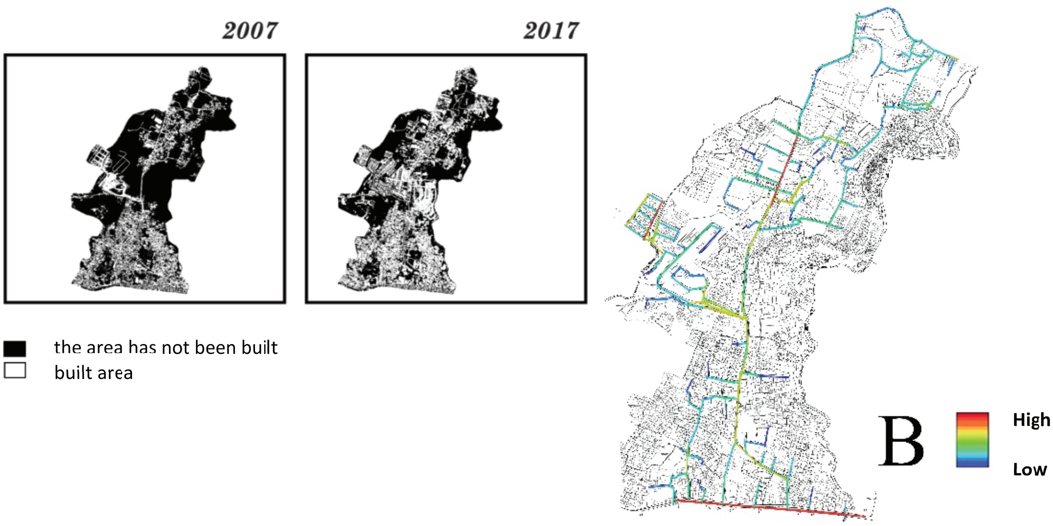

Figure 6: Morphology and road integrity map resulted from space syntax analysis in Pasir Impun area (author's own work).

Compared to others, the Pasir Impun road has the lowest average R2 value (see Table 3,5 and 7). However, the maximum value is lower than Jatihandap road. If viewed from the map results of the analysis (Figure 6), the red road is not located at the base of the road that is connected directly to the primary arterial road of Bandung, but it is in the middle of Pasir Impun road which has the most connections to other roads.

In contrast to Jatihandap corridor, Pasir Impun corridor has the highest value of integrity, connectivity, and choice in the middle of the road. While the value of the

TABLE 5: Integration, connectivity, choice in Pasir Impun road (author's analysis).

Attribute	Minimum	Average	Maximum
Choice R2	0	4.47843	92
Choice [Norm] R2	0	0.173589	1
Connectivity	1	2.86275	11
Integration [HH] R2	0.210897	1.61003	4.60934
Line Length	3.93953	62.102	641.534
Mean Depth R2	1.2	1.58343	1.90909
Node Count R2	3	8.32549	25
RA R2	0.0471014	0.288419	1
Step Depth	0	13.2039	29
Total Depth R2	3	11.7882	41

integrity of the medium more evenly along the road (base to the middle of the road) is. In addition, AH. Nasution road has high integrity value.

In Figure 6, it can be seen that the settlements located in the area tend to be arranged with the octopus morphology form with the density of being inside and heterogeneous. High level of integration on inner roads that integrate between settlements. The combination is spreading in some interior areas. Integration that connects between settlements can be an alternative access to the main road AH. Nasution or from AH Nasution to inner resettlement can be accessed through various channels.

For confirmation, Figure 7 shows Pasir Impun road situation. Congestion occurs on the main road (A). At the base of the road there are motorbike transport bases (ojek) and shops(B). Whereas in the middle of Pasir Impun (the red road) is used for public areas such as sacred space, government facility as well which has the most connections to other roads(C, D). These findings reinforce the theory that space and links may have embedded social significance that has implications for the overall behavior of human habitats [10].

Figure 7: Pasir Impun corridor situation. Congestion occurs on the main road(A), motorbike transport bases (ojek) and shops(B). religious place (C), government facility(D) (author's own work).

Case 3: Cijambe

The next case on Cijambe in 2007, the settlement was originally in the form of octopus morphology and continued to grow until evenly distributed in 2017. The shape of octopus morphology has special characteristics that an area has a center as the core, and the building follows a spinal or branched pattern of the road network. The morphological shape of the octopus is based on the center of the area in the middle area of Cijambe corridor (Table 6 and Figure 8).

Table 6: Characteristic of morphological form in Cijambe area (author's work).

Morphological form	Octopus – with the central area in the middle of Cijambe road
Road-network pattern	Spinal path spinning random but organized (grid) inside
Building density and pattern	Density along the main road, heterogeneous

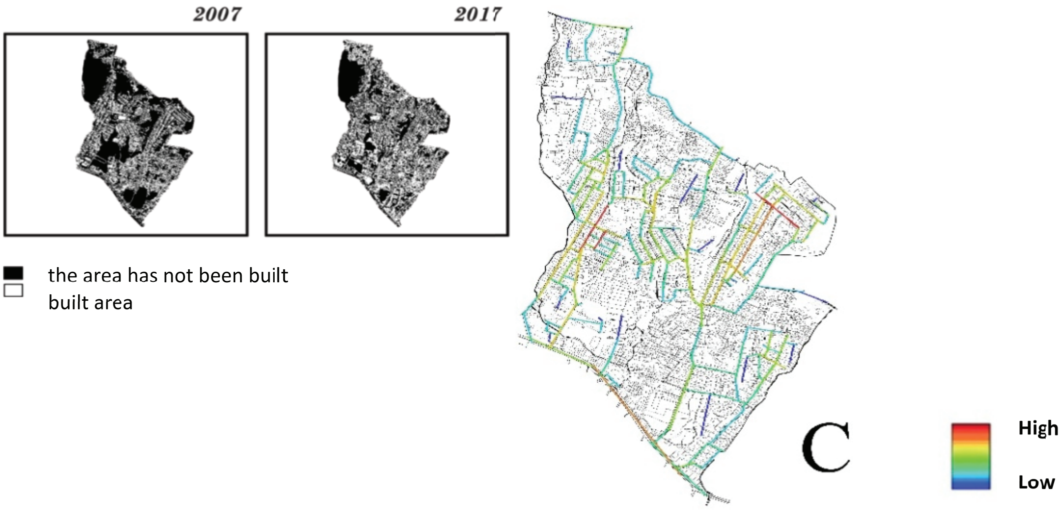

Figure 8: Morphology and road integrity map resulted from space syntax analysis in Cijambe area (author's analysis).

Compared to other cases, this area has the lowest choice value (see Table 3,5 and 7). But it has an average value above Pasir Impun road. This indicates that roads connected to settlements have evenly distributed movements in each area. In contrast to Jatihandap road and Pasir Impun road, Cijambe road has the value of integrity, high and low connectivity that tends to spread within the region. This spread makes the highest value on the road in housing. However, AH Nasution road has high integrity value but not as high as the two previous cases.

In Figure 8 can be seen that the settlements in the area tend to be arranged with morphological forms of octopus with densities inside and heterogeneous. A high level of integration in the inner road that integrates between settlements. The combination

Table 7: Integration, connectivity, choice in Cijambe road.

Attribute	Minimum	Average	Maximum
Choice R2	0	4.83333	40
Choice [Norm] R2	0	0.172427	1
Connectivity	1	2.92063	8
Integration [HH] R2	0.210897	1.6529	3.76563
Line Length	4.87421	77.8822	495.717
Mean Depth R2	1.25	1.60082	1.875
Node Count R2	3	8.75397	22
RA R2	0.0653595	0.258048	1
Step Depth	0	10.004	34
Total Depth R2	3	12.5873	36

spread in several parts of the inner area. Integration that connects between settlements can be an alternative access to the AH. Nasution main road or from AH. Nasution to the inner settlement can be accessed through various roads.

In the last stage (confirmation), Cijambe road situation in Figure 9 (A-B) was taken from AH Nasution. It is similar to high density as Jatihandap and Pasir Impun T-junction. This road is potentially used for public facilities. Cijambe corridor is not identical in the characteristic of settlement compare to Jatihandap and Pasir Impun since the flow of the inhabitants into several estates is well-organized control. In the other side, the interesting information from residents says that the red road in the center of the Cijambe area is quite dense at certain hours (morning and evening).

Figure 9: Cijambe road situation. Figure 9A & 9B are situation taken from AH Nasution. It is similar of high density with Jatihandap and Pasir Impun T-junction. This space is potentially used for public facilities (C). Cijambe corridor tend to have better connectivity quality since the flow of the density in the housing is well-organized and control (author's analysis).

6. Conclusion

Housing and settlement in the periphery of Bandung City from 2007 to 2017 (ten years or a decade) are growing very intensively, especially along the Eastern of Bandung road and corridor. Based on this case study analysis, there are several patterns of housing morphology and connectivity quality. There are exist the degree of housing settlement growth pattern from potentially very isolated or “big settlement pocket” (Jatihandap case), partially pocket (the three cases) into open pattern (Cijambe case). In connectivity perspective, the inter-regional road and local corridor/street experience different degree of integration or disintegration. Several findings indicate it. The first one, residential areas that only have a single road corridor have very high activity intensities because the movement tends to rely on a single corridor. The second one, the area that has an integrated road or connected road from other/outer settlement (or called as alternative outer ring road) tend to spread out the intensity so that the traffic jam at certain hours in the road corridor can be avoided because there are more alternative roads. The third one, the absence of an alternative exit from the secondary road to another primary arterial road to the city causes very high density at the T-junction road.

The other conclusion is related to the confirmation stage: field observations show similar results as space syntax analysis that use digital software. The red line in the integrity map of space syntax analysis in the three cases reflect the very high connectivity (integrity) demand position that potentially led top traffic jam if there is no intervention of space or corridor design pattern. The isolated or “big housing pocket” and the very high intensity or overload integrity in T-junction position become a priority for corridor re-design.

Further studies related to morphology in the urban/city periphery could be done in more detail. Also, studies related to Space Syntax analysis can be used more varied to identify changes in housing and settlement.

References

[1] BPS-Statistics of Jawa Barat Province. (2018). Jawa Barat Province in Figures 2018. 1102001.32 BPS-Statistic of Jawa Barat Province, Bandung.

[2] Tarigan, A. K., Sagala, S., Samsura, D. A., Fiisabiilillah, D. F., Simarmata, H. A., & Nababan, M. (2016). Bandung City, Indonesia. *Cities*, 100–110.

[3] Putri, M. A., Rahayu, M. J., & Putri, R. A. (2016). Bentuk Kenampakan Fisik (Morfologi) Kawasan Permukiman di Wilayah Pinggiran Selatan Kota Surakarta. *Jurnal Pengembangan Kota, 4*(2), 120–128. doi:10.14710/jpk.4.2.120-128

[4] Önder, D. E., & Gigi, Y. (2010). Reading urban spaces by the space-syntax method: A proposal for the South Haliç Region. *Cities, 27*, 260–271.

[5] Mohamed, A. A. (2016). People’s movement patterns in space of informal settlements in Cairo metropolitan area. *Alexandria Engineering Journal, 55*, 451–465.

[6] Choi, A.-S., Kim, Y.-O., Oh, E.-S., & Kim, Y.-S. (2006). Application of the space syntax theory to quantitative street lighting design. *Building and Environment, 41*, 355–366.

[7] Li, Y., Xiao, L., Ye, Y., Xu, W., & Law, A. (2016). Understanding tourist space at a historic site through space syntax analysis: The case of Gulangyu, China. *Tourism Management*, 30-43.

[8] Kim, H.-K., & Sohn, D. W. (2002). An analysis of the relationship between land use density of office buildings and urban street configuration: Case studies of two areas in Seoul by space syntax. *Cities, 19*(6), 409–418.

[9] Kumar, R. (2014). *Research Methodology: A Step-by-Step Guide for Beginners.* Thousand Oaks, California: Sage Publications.

[10] Al_Sayed, K. T. (2014 (4th Edition)). *Space Syntax Methodology.* London: Bartlett School of Architecture, UCL.

[11] Morlock, E. K. (1991). *Pengantar Teknik dan Perencanaan Transportasi (Introduction to Transportation Engineering and Planning).* Jakarta: Erlangga.

[12] Zahnd, M. (2008). *Model baru perancangan kota yang kontekstual.* Yogyakarta: Kanisius.

[13] Tyas, W. I., Danial, D. M., & Izjrail, A. B. (2013). Kajian Bentuk dan Tatanan Massa di Kawasan Bangunan Ci-walk (Cihampelas Walk). *Reka Karsa*, 10.

[14] Hillier, B., & Hanson, J. (1984). *The Social Logic of Space.* Cambridge: Cambridge University Press.

[15] Hillier, B., Burdett, R., Peponis, J., & Penn, A. (1987). Creating Life: Or, Does Architecture Determine Anything? *Arch. Comporth/Arch. Behav, 3*(3), 233-250.

[16] Salheen, M. A. (2003). An application of universal distance using Space Syntax. *4th International Space Syntax Symposium London 2003*, (p. 36). London.