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Study on the deviation and ratio of spatial arrangement patterns in housing and city development to achieve sustainable urban form in Indonesia: Introduction of observations and calculations by space syntax

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Abstract. This paper aims to discuss and summarise research that has been conducted to provide an understanding of the development of spatial patterns of houses, housing, and the city master plan in Indonesia through the space syntax approach. The development of the house and the city essentially follows a basic pattern. This study provides an overview and understanding of the method of development of patterns by a study of deviations and ratios from an earlier pattern. Various approaches are taken to find the development of these structured patterns, both qualitatively and quantitatively. Data is collected using city master plans that are digitalised and analysed using DepthMap software. This study is a comprehensive study that has been carried out that supports sustainable urban forms. The study was conducted on Javanese houses, HBEs settlements, kampongs and three colonial cities in Indonesia. It found an understanding of the development of patterns, deviations, and similarities with previous spatial patterns. The results of this study are expected to guide housing designers, housing developers, urban planners and urban development policymakers to achieve a sustainable urban form.

1. Introduction

The development of the city has occurred through cultural developments, starting with agrarian, simple ways of life, and strong social relations [1]. Sustainability is often discussed in the development of cities worldwide. Likewise, with cities in Indonesia, the Indonesian government implements sustainable development across all of its development programs. But not all of them eventuate to be sustainable plans, one cause of which is inappropriate city planning [2–5].

The spatial planning in the Indonesian cities considers the design and urban planning which is related to various efforts that are being conducted to conserve the suburbs and natural resources [6]. Another study focuses on the spatial arrangement in regards to sustainable urban form influenced by tradition [7], realised in determining the pattern of home constructions, as influenced by traditions passed from generation to generation [8]. In this study, the researchers calculated the depth of the master plans of the colonial Indonesian cities with the help of the DepthMap software [5]. That studies believed that understanding the spatial pattern of the housing society, houses and city are very important, so that. It is

necessary to examine the patterns by implementing the space syntax approach for determining the similarity of the ratios between the patterns.

A few studies carried out in the field of sustainable development in urban cities have investigated the effect of urbanisation [9–11]. For ensuring a proper investigation into the pattern development, the researchers studied the pattern using the depth ratio that compared the different patterns. They used the Depth Calculation (DC) method for the justified graphs and determined the hierarchy of the relationships in the space syntax. DC has also been conducted to calculate the spatial configuration of buildings, both in housing and public buildings [12]. Calculations use justified graphs to determine spatial configurations. [13]. In Japan, DC has been used to find similarities in residential spaces, called the "Oku" [14]. One study used the DC approach for Javanese homes [7]. Another study discussed the depth ratios after comparing the conventional Javanese houses with other Javanese houses. They studied the spatial pattern of home development in Home-Based Enterprises (HBEs) [8]. This space syntax process helped in determining the function of a room in the house and the space hierarchy. This parameter was based on the culture of the region, in which the building was present.

Space syntax was used in many city development projects and was based on accessibility and geometric analysis [15]. A space syntax process determined the layout of all the buildings and city. This parameter was based on the human movement, environment and social interaction [12]. This technique was used for reading the city spaces [16] and the objective space which offers information regarding the association between the social and physical areas. After reading the urban spaces, the operations of an urban system was simultaneously determined [17].

This study was conducted by considering that urban development can be started from a house, settlement, and the scale of an urban area. These three case studies can have an influence in achieving a sustainable urban form. Meanwhile, the spatial syntax calculation approach is used to obtain quantitative pattern calculations. This research conducted a study on the pattern of the housing, house, kampongs, and the Indonesian cities that were under the Dutch colonial rule. Furthermore, conducted collecting the data and carried out depth calculations for every floor and master plan. Results of the study would help in understanding the depth calculation for every spatial arrangement of the Indonesian houses, house, kampongs, and colonial cities. That will help the researchers determine the deviation in their plan with the primary pattern. This study aimed to calculate the depth ratio of all houses, housing society and colonial Indonesian cities. Results were presented as DC values, which helped in resolving the issues which arise from the housing and city development. The study helped in developing the spatial pattern of the Indonesian houses, housing societies and colonial cities. It also contributed to the research related to the justified graph application of space syntax.

2. Methods

The three objects of research studies were carried out using three different models, but still using spatial arrangements in spatial planning. The house pattern uses the justified graph calculation standard as the basis for the syntax space approach. In the study of settlement, HBEs used a pattern development approach based on their effect on urban access. In the study of cities using depth and connectivity calculations using DeptMapX software, comparisons were made with cities in Amsterdam, Delft, Bandung, Semarang, and Malang. In the study in 5 thematic kampongs, a study of the calculation of depth and connectivity was carried out using DepthMapX to determine the complexity of the kampong patterns.

2.1. Sustainable urban form and space syntax

The layout of the city affects its sustainability, i.e., size, shape, density and the usage of the city. A few cities survive locally but remain unprofitable [18]. The consequences of the progress of a city's sustainability have already been made; the relationship between the form of the city and a sphere of elements of the city on each geographical scale exists. If an understanding of this relationship is obtained, steps can be taken to achieve a sustainable city form. The process of analysing the space used is shown as a network graphic (Figure 1) [13].

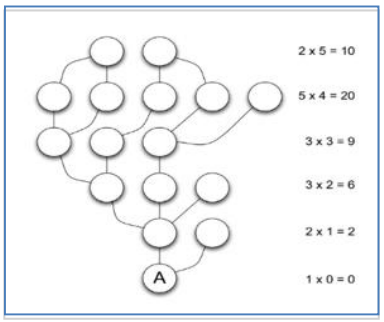

Figure 1. Justified graphs [13].

In this technique, the researchers calculated the depth for the floor plans of the houses, kampongs, and cities. Thereafter, they calculated the depth of the floor and master plans.

2.2. Research steps and research objects

The research was first carried out in Javanese houses in the city of Yogyakarta, Home-based Enterprises (HBEs) settlements in the Malang city, three colonial cities in Indonesia, and five kampongs in Malang city. For colonial cities and the kampongs used DepthMap X for calculating the depth and connectivity. Also calculating the master plans in the cities of Malang, Semarang and Bandung in Indonesia, which were initially planned and developed by Herman Thomas Karsten [19].

Steps involved in the DC process are: (1) Digitising the old maps and inserted into a DepthMapX program. This program only imported the maps from the DXF files [20]. (2) The raster image is converted to the vector image which is processed using the AutoCAD software. The maps are altered from the line to polyline for improving the run time calculation of the DepthMapX program. (3) Then, the depth must be determined. (4) Determine the statistical significance of the data that was generated using the DepthMapX program. Research planning for calculating the master plan pattern is as follows (Figure 2):

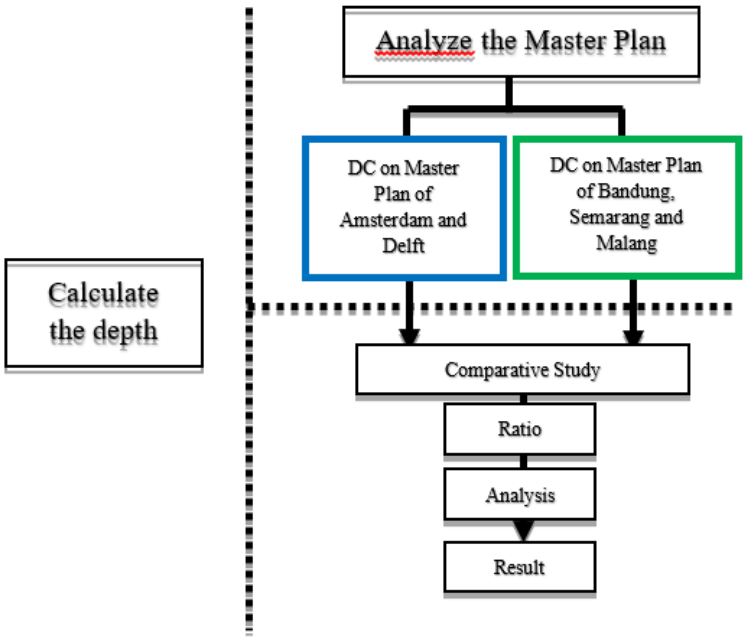

Figure 2. Research plan of DC on master plan.

3. Results and discussion

3.1. Spatial arrangement of Javanese houses

In this study, an analysis of Basic Javanese Houses and their basic hierarchy is carried out (Figure 3) and indicates the relationship between rooms. Thereafter, the hierarchy of every room was determined. This is followed by the visualisation of the position of a room and amount of space in that room based on the conditions that occur in the general Javanese houses. The next process carried out a depth calculation analysis with the help of the Basic Javanese House Justification Graph (Figure 4). They used the conventional Javanese house as the reference for determining the TD of the house. TD refers to the sum of depths in every room of the house. The terrace (1) was regarded as the reference point in a house and had a value of 0. The result that was calculated using the resultant graph was seen to be 34.

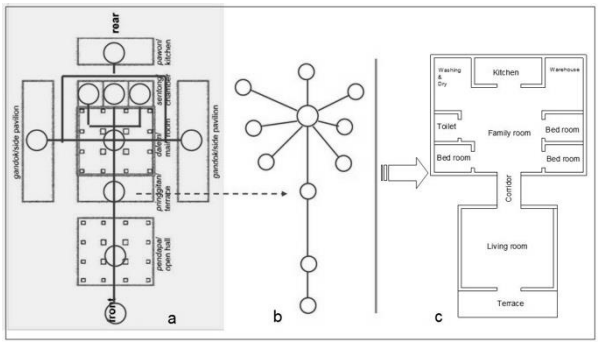

Figure 3. Pattern that highlights the relationship between the rooms in the Basic Javanese House.

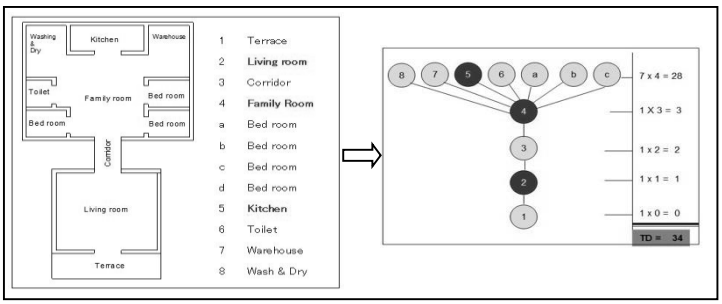

Figure 4. The justified graph of the Total Depth (TD) for Javanese houses.

A Javanese house was seen to be more open, used a higher connectivity level and was grouped. The results in this study noted that the Javanese houses had a more flexible living room, indicating that they had a higher interaction in their houses. The Javanese family room could be used to receive the guests under certain conditions. This family room showed a lower flexibility level as they adhered to the Javanese rules, as it was used for the families.

3.2. Spatial arrangement of the HBEs housing

The study on HBE housing shows that location and economic level were significantly based on the pattern of housing construction. There are four alternative developments in houses that are located far from the main road. Whereas in houses close to kampong roads, the front of the house is prioritised for economic activities (Figure 5).

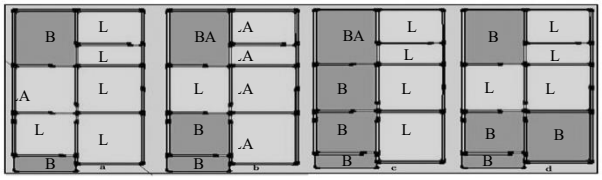

Figure 5. Kitchen was always at the rear of the house and was regarded as the business zone

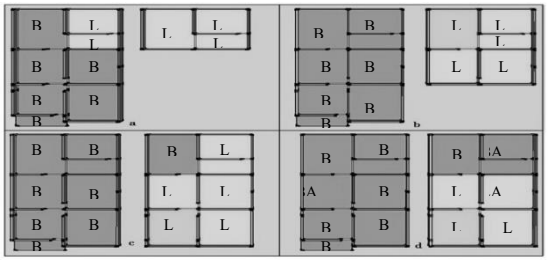

Figure 6. The houses which were located near the main street.

The location of houses located near the main road of the city further expands its utilisation of space for economic purposes. This has a significant effect on the appearance of the house (Figure 5). Based on the patterns, it was noted that the location of a house determined the pattern of the house; i.e., when it was closer to the main road, there was a higher opportunity to use the available land for maximising the business activities.

3.3. Spatial arrangement of the colonial cities in Indonesia

The researchers used a DepthMapX program that was developed using space syntax networks. The study was done by calculating old maps (Amsterdam, Delft, Bandung, Semarang and Malang). The conversion process was done using the AutoCAD program from raster to vector and calculations were performed using DepthMapX in the form of statistical calculations (Figures 7-11).

Figure 7. Old Map of Amsterdam, 1904.

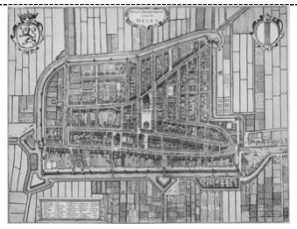

Figure 8. Old map of Delft, 1649.

Figure 9. Old Map of Bandung, 1917.

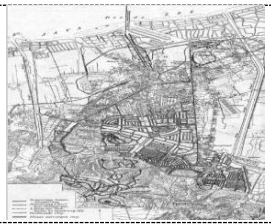

Figure 10. Old Map of Semarang, 1919.

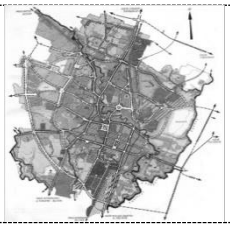

Figure 11: Old Map of Malang, 1933.

In this study determined all DCs in the colonial Indonesian cities and Dutch cities and compared the findings. Thereafter, conducted calculating the ratio values for the City Hall, Station and the City Square.

A predetermined map was converted in the Visibility Graphs (VGA), which was used for carrying out a Visual Step Depth (VSD) evaluation to determine the depth in the map.

The statistical results showed a similarity ratio after comparing the TD ratio in the Dutch cities. Thereafter, the researchers compared the DC values for the colonial Indonesian cities of Bandung, Semarang and Malang. For determining the ratio of the depth of a region, the researchers determined the Base Depth Ratio (DR) and Depth Deviation (DD) values. The DD value for the specific region and TD for Amsterdam and Delft, along with the DD from City Square (DDCS), DR from City Hall (DRCH), DR from City Square (DRCS), and DD from City Hall (DDCH).

Table 1. Total depth and ratio of city square and city hall.

Cities	Total Depth	Depth of City Square	Depth ratio of City Square	Depth of City Hall	Depth Ratio of City Hall
Amsterdam	12	6	0,5	2	0,17
Delft	20	4	0,2	1	0,05
Bandung	13	3	0,23	3	0,23
Semarang	13	3	0,23	3	0,23
Malang	12	6	0,5	3	0,25

Source: DepthMapX software calculation results

Table 2. Total connectivity and ratio of station.

Cities	Total Connectivity	Connectivity of Station	Connectivity Ratio of Station
Amsterdam	19554	3575	0,18
Delft	15929	1546	0,10
Bandung	2563	329	0,13
Semarang	5480	1008	0,18
Malang	6028	1096	0,18

Source: DepthMapX software calculation results

The TD value in each Indonesian city, especially Malang, was similar to those noted for Amsterdam (Table 1). The connectivity ratio for the station area was seen to be relatively low in every city (Table 2). Also, the depth value noted for Malang was similar to the TD value of Amsterdam. A significant similarity was noted in the pattern of the master plans of the colonial cities that were planned by Herman Thomas Karsten. This quantitative approach can see similarities based on statistical data generated by DepthMap software. This method will provide an easier and faster way without observing and asking respondents who need more time to collect data. The physical image indicated that the morphologies of the colonial Indonesian cities and Amsterdam were similar. Hence, when the researchers did not use a syntactic space, it was presumed to differ in the hierarchy. Using this method found significant similarities between these cities because the calculation uses VSD and Connectivity.

3.4. Spatial arrangement of Kampong in Malang city

The study was conducted in five thematic kampongs in the city of Malang, namely the kampong *Warna-Warni*, kampong *Tridi*, kampong *Kayutangan*, kampong *Dinoyo Ceramic,* and kampong *Putih.* The location of these five urban kampongs is in the centre of Malang and has a special theme, so this kampong looks unique and becomes an attractive tourist destination for tourists. After determining the VSD, ASD, MSSPA, MSSPL, and MSLD, statistical analysis was performed on the Visibility Graphs (VGA) that had been made before (shown in Table 3).

Table 3. Depth calculation.

No.	Kampong	VSD	ASD	MSSPA	MSSPL	MSLD
1	*Warna warni*	12	5.21	5.94	229.74	192.48
2	*Tridi*	5	2.37	3.07	226.33	212.94
3	*Kayutangan*	8	3.88	4.02	14560.4	10200
4	*Keramik Dinoyo*	9	3.28	3.12	59481.5	37036.3
5	*Kampung Putih*	8	3.41	3.43	11135.4	10627.2

Depth on VSD and ASD in Kampong Warna-warni is higher (12 and 5.21) than in Kampong Tridi (5 and 2.37). This is caused by the many access routes to the Kampong Warna-warni area. Whereas in kampong Kayutangan and kampong Dinoyo Ceramic the depth is relatively the same (table 3).

Table 4. Connectivity.

No	Kampong	Average	Min.	Max.	Std. Dev.	Total
1	*Warna warni*	6200.03	217	15799	4607.67	34567
2	*Tridi*	1584.94	51	4676	1057	9647
3	Kayutangan	837.82	133	2494	506.18	16503
4	Keramik Dinoyo	3508.51	127	10346	1760.65	39905
5	Kampung Putih	3004.16	508	6353	1340.45	30447

Connectivity in Kampong *Warna-warni* is also higher (6200.03) than in Kampong *Tridi*, this is caused by more varied access and circulation, which causes high connectivity. While the lowest is kampong *Kayutangan* (837.82). But the highest total connectivity was in the kampong *Dinoyo Ceramic* (39905), this was due to a T-junction connecting all access to the kampong (table 4). It was found that the total depth was similar in the three kampongs (*Kampong Kayutangan, Kampong Dinoyo Ceramik*, and *Kampong Putih*), while significant differences were found in *Kampong Warna-warni* and *Kampong Tridi*.

4. Conclusions

In the understanding of spatial arrangements, the syntax of space must be paid attention to because the arrangement of space is very important in knowing the development of a pattern of space. Four studies investigated the homes and presented the depth ratio that indicates whether a room is flexible or not, this was found to affect the development of a house. In the context of housing, calculations are made of changes in patterns of houses caused by economic development. The higher the depth, the higher the hierarchy in the kampong (access to the kampong has many intersections and paths), thus indicating different levels of spatial syntax in each kampong. While in the city context, by doing a comparison of depth and connectivity, the deviation and similarity ratio in the master city plan of the parent city can be seen. It can be concluded that in determining the spatial pattern of a house, housing, and urban area, it can be done by manual methods and using simulation software. Integration from the smallest unit, namely the house to the urban area in the form of a master plan, can help determine the basic pattern, so that it will become a guide in realizing a sustainable urban form. This will also help where the city is developing due to urban growth. From the four studies that have been conducted, it can be concluded that the space syntax approach is very helpful in determining and directing the development of the house, housing, kampongs, and cities. This is expected to help designers, planners and policymakers to determine the direction of development required to achieve sustainable urban form.

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