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Measuring Spatial Arrangement of Indonesian Colonial Cities using Depth and Connectivity Calculations: Ratio study on master plans using Space Syntax

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Key words: Colonial Cities; Connectivity; Depth; Space Syntax

Abstract: This study proposes an easy method for calculating the spatial arrangement of Indonesian city planning, in line with sustainable urban forms. Several Indonesian cities originated during the Dutch colonial era. Although it is very important to consider the original plans of these cities to maintain their sustainability, generally, the original plans tend to be ignored. The master plans investigated in this work are those of three cities in Indonesia designed by Dutch planners of Semarang, Bandung, and Malang, and which are compared to two cities in the Netherlands (Delft and Amsterdam). The method used was by collecting images of ancient maps of Amsterdam, Delft, Bandung, Semarang, and Malang, then digitising the image from raster to vector so that it can be calculated using DepthMapX. This study utilised maps for computing the Depth of the cities. Then, a space syntax approach using Depth Calculation (DC) techniques is deployed for determining the similarity ratio among the cities. Based on the results of the assessment, it is found that there is similarity in Depth in the cities of Amsterdam and Delft against three Dutch colonial cities in Indonesia. This study supports that the DC in the master plan of cities in Indonesia is similar. The resulting ratio shows the extent of the difference between the pattern of Indonesian colonial cities and the pattern of Dutch cities. It is expected that this study will contribute to urban planners' and city governments' determination of the direction of development of a city designed during the Dutch colonial period. Maintaining the sustainability of the old colonial urban form requires harmony between urban planning and the policies made by the city government.

1. INTRODUCTION

Indonesia is a country whose development cannot be distinguished from its colonial state, namely the Netherlands. Indonesia was colonised by the Dutch more than 350 years ago. The development of the Dutch colonial city in Indonesia was initiated by the Indonesian civil authorities, who accepted modern planning ideas in 1905 by merging many cities in most of Java into urban municipalities with city councils (Cobban, 1992; Flieringa, 1930).

During this long period of colonialism, there was a transformation in a special master plan scheme for urban growth and progress. The Dutch wanted to build on a city model like the one in the Netherlands, and the architecture in colonial cities was imagined to be very similar to that in the Netherlands (Cobban, 1992; Coté, 2014). However, in its development, the cities built with the colonial model in Indonesia experienced changes. Colonial cities in Indonesia were thought to follow the same design hierarchy as the master plan in the Netherlands. To support sustainability in Indonesian cities based on the colonial model, it is important to analyse the number of similarities between cities in Indonesia and the Netherlands. This hierarchy can be measured by calculating and comparing the Depth and Connectivity of cities in Indonesia and the Netherlands.

Colonial cities in Indonesia were originally located side by side with the royal palaces, as it was very much in the political interests of the Dutch colonisers to approach the Indonesian kings. Although side-by-side, the boundaries between the colonial city area and the palace were very clear, and there were in effect two governments in each region (Colombijn & Coté, 2015; Yapp, 2020). Following the desire of the Dutch to build cities along the same lines as those in the Netherlands, the architecture of buildings in the colonial cities was very similar to the architecture in the Netherlands (Coté, 2014). However, the subsequent development of the colonial towns in Indonesia has steadily caused the decline of colonial city planning. Research works in other nations also talked about urban planning, the Government of Taiwan's endeavour to conserve a few of the historical zones of Taipei, the sustainability of structures in a region in Malacca (Go & Lai, 2019; Ismail, 2012) and other historical towns (Drummond, Stier, & Diffendorfer, 2019; Subadyo, Tutuko, & Cahyani, 2018). Some research works have been conducted on colonial cities, such as participatory approaches (Agrawal, 2010), economic and political research (Blatman-Thomas & Porter, 2019; Rodríguez-Alegría, Millhauser, & Stoner, 2013; Yi & Ryu, 2015) and sustainable development in urban cities because of the impact of urbanisation (Buchori & Sugiri, 2016; Firman, 2009; Li & Mao, 2019; Qiao et al., 2019; Tutuko & Shen, 2016; Tutuko, Subagijo, & Aini, 2018). Other research works using DC have been carried out by Tutuko and Shen (2014a) on Javanese homes. The research noted the depth ratio of specific rooms gauged by comparing the basic Depth of the Javanese home. A study was formulated by Tutuko and Shen (2014b) on Home-based Enterprises (usually abbreviated as HBEs) for ascertaining the development patterns of a house. In order to further deepen understanding, the Space Syntax approach based on justified graphs took the research works down to a city scale. Space syntax research on DC was also conducted by Dawson (2002) for computing the spatial configuration of public and residential buildings. Depth Calculation was carried out by utilising the justified graphs which were not considered in Dalton and Dalton (2007) for ascertaining spatial configurations. The research by Kigawa (2003) on similarities through DC for ascertaining "Oku" (Depth) utilises boundaries in space based on the pattern of occupancy and an area in Japan. Through the space syntax approach, it can be noted that vital space has a similar shape in the layout of its functions. Ascertainment of the hierarchy of space is acclimatised by the culture prevailing in the region. Cultural demands put the space or function straightaway where it has to be.

In order to achieve urban growth, the goal is to create high-quality space that is easy for the public to access (Brad, Murar, & Brad, 2016). Some studies discuss the pattern and morphology of a city with many different approaches, for example, by using "the image of the city" by Lynch (1960), who is very influential in urban science. Another study also discusses how people perceive and represent a city, how the image of a city can be seen from an urban physics perspective and will discuss this using a computational approach (Filomena, Verstegen, & Manley, 2019). In developing a city, radical developments are sometimes needed to address urban issues, such as low-carbon innovations (Tyfield, 2018). Another study discusses quantifying the problematic situation in a region in Turkey to improve the area. This is done by exercising strict control over physical and functional changes in Istanbul (Agirbas, 2020). It is important to understand the development of a city's original pattern to achieve such ends. In order to specifically supplement the study about colonial city development, this research study considers urban patterns by making use of the ratio drawn by comparison amongst the master plans of diverse cities. This method employs depth calculation of the usual justified graph to establish a hierarchy chart of relationships associated with the space syntax.

Law et al. (2012) studied space syntax in terms of a city-scale. The study concentrated on city development by integrating geographic accessibility analysis and geometric analysis. The city development could be viewed from its mobility due to accessibility of the city's prevailing transportation modes. As a network, the geometric patterns and geographical conditions of a city could be adopted. Space syntax analysis could justify the significance of Connectivity of on-road patterns when considering long-term activities in traditional places and environments surrounding the city, which allows the formed outer space to motivate social interaction and increase the frequency of meetings (Can & Heath, 2016).

The space syntax approach is generally applied based on the layout of buildings as well as cities. Space syntax covers a set of theories as well as quantitative, analytical and descriptive tools to analyse spatial formations at various scales: buildings, cities and interior spaces (Dalton, 2005; Hillier, 2007; Hillier & Hanson, 1984; Oteng-Ababio, Smout, & Yankson, 2017; Prasertsubpakij & Nitivattananon, 2012). A different study reported that space syntax concentrates on lines (e.g. passages, streets) and offers good guidance regarding the assessment of a space layout (Batty, 2004). For an urban area, the environment of social interaction and human movement impacts this (Dalton & Dalton, 2007; Dawson, 2002). City space can be read via the space syntax method (Hillier, 2007) and is also helpful to read objective space, which suggests that a relationship exists between the social and physical structure. When investigating urban space readings, the operation of urban systems could be read related to building structures (Önder & Gigi, 2010).

The current study takes as objects the patterns of cities in Indonesia colonised by the Dutch, these often-called colonial cities. This study tries to provide a method and understanding different from previous studies in determining a city pattern and comparing the Depth and Connectivity with its parent city. Furthermore, master plan data collection or city planning was carried out in the past and calculations of Depth were run on each master plan. Depth calculation in master plans of big cities in the Netherlands is used as basic Depth. The study's results are expected to be in the form of calculation formula for the Depth of colonial cities in Indonesia. The aim is to determine the differences ratio in the colonial cities planning to their parent cities. Through the depth ratio, it is expected to show how much difference occurs and provide information to the local government.

The key study objective is to determine the ratio of Depth of the master plans on colonial cities situated in Indonesia versus the master plans of cities situated in the Netherlands. The research outcome is in DC form. It could help in resolving issues arising from cities' development. Thus, other goals are anticipated, i.e.: (1) To set the number of different patterns of colonial cities situated in Indonesia and other cities situated in the Netherlands and (2) to compare the total Depth (TD) as well as the Depth of the colonial city situated in Indonesia. Thus, this research is an effort to complement the study of the development of colonial cities situated in Indonesia and the study associated with the application of justified graphing on space syntax. Because of intrinsically colonial features in Indonesian cities, the results are expected to aid in addressing development issues in urban areas by employing a method of sustainable urban form.

2. LITERATURE REVIEW

2.1 The Development of Colonial Cities in Indonesia

The development of cities in Indonesia cannot be separated from the history of Dutch colonial occupation, which lasted for almost 350 years. At the beginning of the ancient city development in Indonesia, cities in the Archipelago (Ancient Indonesia) did not have a basis for planning that could be learned. The Dutch began to enter Indonesia through cities that became trade centres, such as Batavia (Jakarta). Urbanisation began to put pressure on these multicultural cities, and the colonial government faced problems because urban spatial arrangements divided the land in the city.

The separation of space in the city is a feature of the colonial city, which was mainly based on the nations that lived. Furthermore, according to Suprayoga (2008), one of the important milestones in the management of cities in Indonesia was the emergence of a decentralisation law that allowed the city government to regulate its city affairs. Cities in Indonesia then imposed building regulations, such as the *Bataviasche Plannerernerning* 1941, *Bataviasche Bestemingkringe en Bouwtypenverordening* 1941, and *Bataviasche Bouwverordening* 1919-1941. However, all these regulations were still oriented to the physical city. Contemporary discourses inspired a study on the development of colonial cities in Indonesia during the Dutch administration through good planning by Herman Thomas Karsten on modernity and critiques of Western civilisation (Cobban, 1992; Coté, 2014; Yapp, 2020). Several studies discuss Amsterdam as a city whose development model is a role model for other countries in Europe and a way of intensifying urban land use while improving spatial quality (Kahn & van der Plas, 1999; Savini et al., 2016). While the city of Delft is famous for being associated with the Dutch royal family, Delft Blue pottery, its canals, historical centre, ancient merchant houses, old churches, and the beautiful town hall - Delft is over 750 years old - the city was also occupied by the Dutch East India Company (VOC) and played a very influential role in the Dutch Golden Age (Huerta, 2003; Ruestow, 1996). From this reference, it can be concluded that there is a very close relationship between urban design patterns in Indonesia and the Netherlands, so it can be assumed that there is an influence on the development of its Dutch cities.

2.2 Sustainable Urban Forms

In the concept of sustainability in an urban area, the economic, social and environmental consequences become the basis for urban sustainability; this is a new urbanisation theory. Urban development is required to achieve a vital symbiosis between city and nature (Basiago, 1996). The shape of a city could influence its sustainability by its shape, size, density, and the city's use. Some shapes of cities may survive locally but, more broadly, do not always become more profitable (Gibbins, 2001). The aftermath of the city's sustainability has been formed; the relationship between the city's form and a sphere of city elements on every geographical scale must exist. If an understanding of this relationship is gained successfully, steps can be taken to achieve a sustainable city form.

The physical form of the city itself mostly causes problems for cities that are not sustainable. Urban sprawl causes urban populations to move to suburban areas with more land area, while downtown areas become abandoned. In the city's current development, there is often development that ignores the previous form of the city, which will conflict with the concept of sustainable urban form. We cannot prevent the city's development, but with the form or arrangement of cities that must be maintained, the planning is expected to be directed.

2.3 Space Syntax

Related to Dalton and Dalton (2007), space syntax is a theory and approach related to the proximity between the complicated spatial structure and humans. Space syntax models and analyses a city by using city space as the basic generator of a city. This approach is supported by social space theory (Karimi, 2018). The subsequent development of space syntax theory explains the logic of society in manifesting spatial systems, unification of space, spatial configuration, spatial relations, space visualisation, and movement in small domestic spaces and large-scale cities (Penn et al., 1998). This methodology can be used up in wide-scale urban regions and for complicated settlements and buildings. The core of all space syntax explanation is the notion of network graphs.

3. METHODS

The approach of this research focuses on calculating the Total Depth (TD) on the master plans of Amsterdam's city and the city of Delft (*Figures 1-2*). Post that, calculation is performed for the Depth of the master plans in Bandung city, Malang city and Semarang city (*Figures 3-5*). The three cities situated in Indonesia are considered to have been arranged by Herman Thomas Karsten (1885-1945) (van Roosmalen, 2011). Amsterdam and Delft were selected due to the fact that Amsterdam was hometown to Herman Thomas Karsten in 1920. He learned construction engineering at Delft. Therefore, architecture development and education of the Netherlands are greatly triggered by these two cities, Amsterdam and Delft. The part of the city where the similarity comparison is carried out is at the central station, city square, and town hall, with the consideration that these three places are evident within the cities to be studied, based on the urban planning pattern in the Netherlands and its colonies. The main station of the city is the starting point, which was chosen taking into account that in the Netherlands, the term "Central Station" is considered a centre of mobility relating to the arrival and departure within a city.

Figure 1. Old map of Amsterdam, 1904

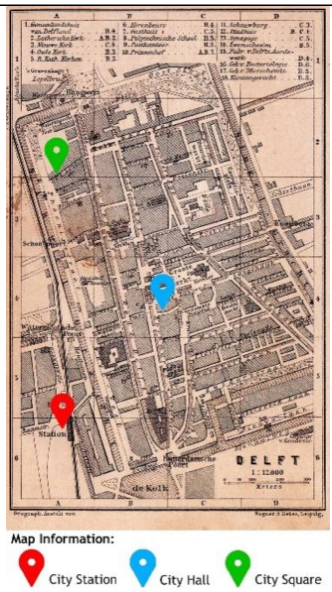


Figure 2. Old map of Delft, 1649

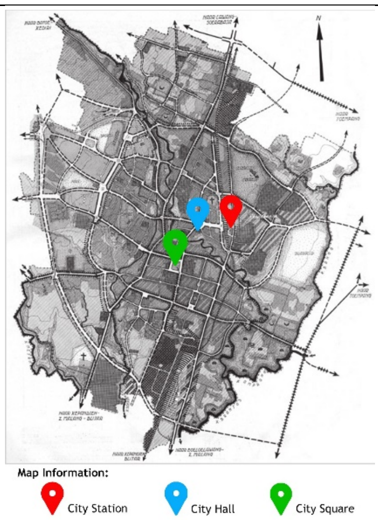


Figure 3. Old map of Malang city, 1933 (van Roosmalen, 2011)

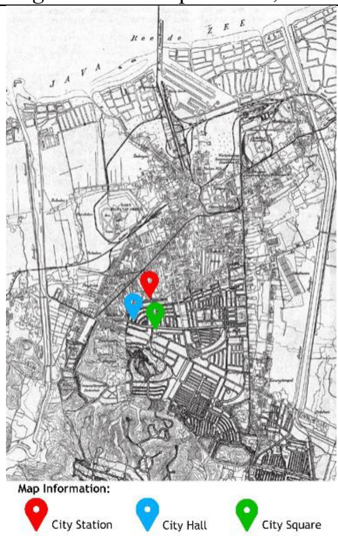


Figure 4. Old map of Semarang city, 1919 (van Roosmalen, 2011)

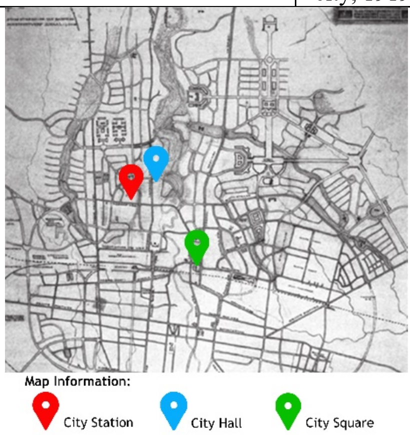


Figure 5. Old map of Bandung city, 1917 (van Roosmalen, 2011)

3.1 Calculation Methods

Basically, the graph is regarded to be undirected and possesses no weight such that long and short lines get decreased to dimensionless vertices, thus efficiently eliminating the metric distances from the analysis. In an axial map, longer lines were inclined to possess a greater number of intersections amongst each other. Lines that are more connected in the graph are likely to be more integrated or shallower. For each line, the measure of spatial integration can be defined as the average Depth of that line based on all other lines for a defined number of steps (or radius) (Penn, 2001). This study also considered distance and curvature, which are considered visually for the movement and hierarchy of space. This is intended to get a more comprehensive measurement of space syntax.

Furthermore, to add spatial analysis, the calculation is based on distance and angular Depth. This is needed to get a more detailed calculation based on human behaviour moving and going somewhere (Hillier & Hanson, 1984). This calculation used space syntax analysis, including Angular Step Depth (ASD), which is the calculation of Depth based on angular views; Metric Step Shortest-Path Angle (MSSPA), to calculate the shortest relative path distance at a certain angle; Metric Step Shortest-Path Length (MSSPL), to calculate the shortest relative path distance at a certain length and Metric Straight-Line Distance (MSLD), to calculate the direction of a straight line with a certain distance.

3.2 Research Plan

This research has been segmented into two stages: (1) determining DC in colonial cities in Indonesia and the Netherlands, and carrying out a comparative study of DC for both countries to accomplish the ratio of similarity (*Figure 6*); and (2) involving the calculation of the ratio on the Station, City Hall and City Square.

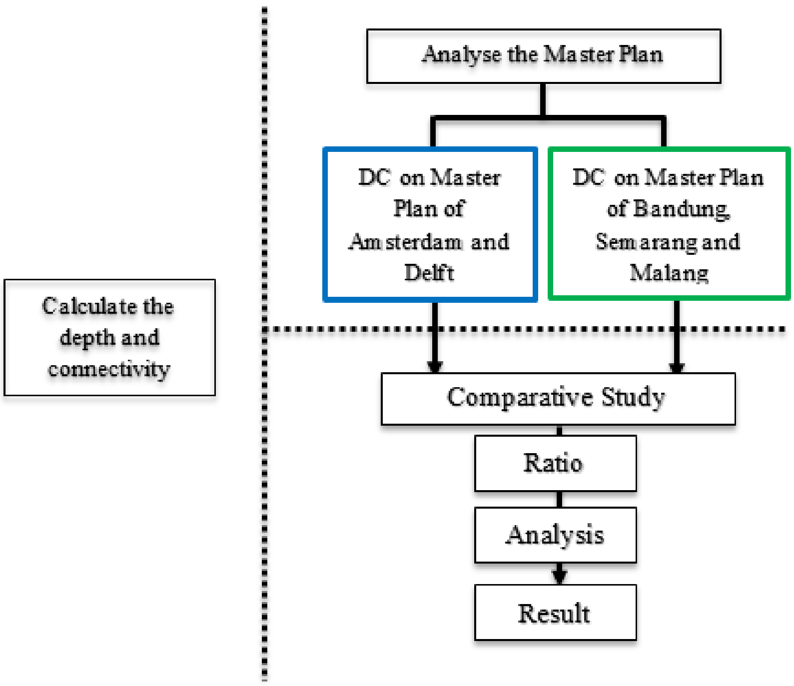


Figure 6. Research plan

3.3 Steps of DC

For doing DC, the steps that need to be carried out are:

1. Digitisation of old maps on Amsterdam, Bandung, Delft, Malang and Semarang. First, it is important to insert map images into the software DepthMapX. The DepthMapX software is limited to importing maps only from DXF format files (Turner, 2007).
2. From the raster image, the process is conversion to a vector to allow processing in AutoCAD. In addition, maps were upgraded from line-to-line polyline to speed up the calculation of running time related to DepthMapX software.
3. The depth determination of the master plan with regards to Indonesia and the Netherlands.
4. Calculate the generated data from the DepthMapX software statistically.

Due to the maps obtained from ancient images as JPEG, it is necessary to make adjustments compared to Google Earth maps to determine whether they are roads or buildings, trees, or other city facilities. Therefore, the calculation process using DepthMapX software was done repeatedly by making adjustments to the scale in each master plan to get the same basic measurement on AutoCAD; if it is not the same, the resulting calculation will not be proportional to the scale of the real city.

It is important to carry out a comparative study for VSD and Connectivity related to the research's aim. The similarity ratio can be determined by first comparing the Total Depth (TD) ratio concerning the Netherlands. The next step would be to perform DC comparison in sequence in Bandung, Malang and Semarang. In order to get the ratio of Depth in the specific areas, the determination of Depth Deviation (DD) and the Basic Depth Ratio (DR) is important. There is a certain deviation between the Depth on a specific area and the Total Depth (TD) applicable for these two cities (Amsterdam and Delft). The DR of City Square (DRCS), DR of City Hall (DRCH), DD of City Square (DDCS), and DD of City Hall (DDCH) are shown below:

$$DRCS = \frac{DCS}{\overline{\overline{TD}}} \longrightarrow DDCS_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad (1)$$

$$DRCH = \frac{DCH}{\overline{\overline{TD}}} \longrightarrow DDCH_x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} \quad (2)$$

4. RESULT

In executing DC, it is important to calculate the starting point. First, conversion of the predefined maps into Visibility Graphs (VGA) had to be done. Next, the VGA map was employed to calculate Visual Step Depth (VSD) to determine the map's Depth. At the same time, based on these results, it is also assumed that Connectivity occurs on the VGA map (*Tables 1-2*).

After determining the Connectivity and Visual Steps Depth (VSD), statistical analysis is carried out on the Visibility Graphs (VGA) that have been built (*Tables 1-2*). According to *Table 3*, the Total Depth for these three cities in Indonesia is similar to Amsterdam, particularly Malang. On the other hand, the connectivity ratio considered in the station area was seen to be comparatively low in those cities (*Table 4*).

Table 1. Connectivity and VSD of Amsterdam and Delft, calculated using DepthMapX

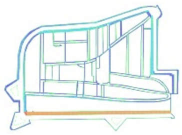
Cities in The Netherlands	Connectivity		VSD	
Amsterdam		Average 3,508.64 Minimum 46 Maximum 19554 Std Dev 2858.45 Count 298,138		Average 5.37 Minimum 0 Maximum 12 Std Dev 1.96 Count 298,138
Delft		Average 3,377.73 Minimum 20 Maximum 15,929 Std Dev 4,246.41 Count 82,336		Average 6.50 Minimum 0 Maximum 20 Std Dev 4.28 Count 8 82,336

Table 2. Connectivity and VSD of Bandung, Semarang and Malang, calculated using DepthMapX

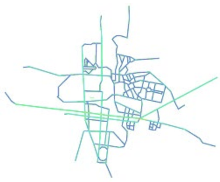
Cities in Indonesia	Connectivity		VSD	
Bandung	 Std Dev 311.22 Count 20,079	Average 370.33 Minimum 30 Maximum 2,563	 Count 20,079	Average 4.32 Minimum 0 Maximum 13 Std Dev 1.84
Semarang		Average 1,112.66 Minimum 22 Maximum 5,480 Std Dev 1,238.39 Count 40,918		Average 4.03 Minimum 0 Maximum 13 Std Dev 2.15 Count 40,918
Malang	 Count 94,903	Average 1,251.02 Minimum 9 Maximum 6,028 Std Dev 988.15	 Count 94,903	Average 5.70 Minimum 0 Maximum 12 Std Dev 2.70

Table 3. Total Depth and Ratio of City Square and City Hall

Cities	Amsterdam	Delft	Bandung	Semarang	Malang
Total Depth	12	20	13	13	12

Depth of City Square	6	4	3	3	6
Depth ratio of City Square	0.5	0.2	0.23	0.23	0.5
Depth of City Hall	2	1	3	3	3
Depth Ratio of City Hall	0.17	0.05	0.23	0.23	0.25

Table 4. Total Connectivity and Ratio of Station

Cities	Amsterdam	Delft	Bandung	Semarang	Malang
Total Connectivity	19,554	15,929	2,563	5,480	6,028
Connectivity of Station	3,575	1,546	329	1,008	1,096
Connectivity Ratio of Station	0.18	0.1	0.13	0.18	0.18

As presented in *Table 5*, the Depth of the Malang city square was similar to Amsterdam city square (deviation 0). Regarding the deviation of station connectivity (*Table 6*), the results of calculations in Malang and Semarang were very similar compared with those of Delft and Amsterdam.

Table 5. Depth Deviation among cities

Cities	Bandung	Semarang	Malang	Cities	Bandung	Semarang	Malang
Depth Deviation with Amsterdam	0.71	0.71	0	Depth Deviation with Delft	4.95	4.95	5.66
Deviation of City Square	0.19	0.19	0	Deviation of City Square	1.18	1.18	3.91
Deviation of City Hall	0.05	0.05	0.06	Deviation of City Hall	0.13	0.13	0.14

Table 6. Connectivity Deviation among cities

	Bandung	Semarang	Malang
Connectivity Deviation of Station with Amsterdam	0.04	0	0
Connectivity Deviation of Station with Delft	0.02	0.06	0.06

The results of the calculation of Angular Step Depth (ASD), Metric Step Shortest - Path Angle (MSS-PA), Metric Step Shortest - Path Length (MSS-PL) and Metric Straight - Line Distance (MS-LD) of the five-city maps are as follows (*Table 7*).

Table 7. The calculation of ASD-MSSPA-MSSPL-MSLD

Cities	ASD	MSSPA	MSSPL	MSLD
Amsterdam	4.74	13.02	159,626	112,823
				
Delft	11.88	18.52	5,601.98	1,583.74
				
Bandung	5.5	8.13	43,011.4	39,006.3
				
Semarang	6.81	7.29	225.41	181.98
				
Malang	5.8	8.67	2,710.07	2,568.49
				

Table 7 shows that the highest ASD value is Delft (11.88), and for the cities of Bandung, Semarang and Malang there is not much difference. Delft also has a higher MSSPA value than Amsterdam (18.52), which means that Delft has the shortest angular shortest path in its master plan. In contrast, Amsterdam has a higher MSSPL value (159,626) and a higher MSLD (112,823). This is significant compared to Delft, which shows that the map of Amsterdam has more short routes and has more straight lines in the city. In comparison, the cities of Bandung, Semarang, and Malang have similarities in ASD and MSSPA. While from MSSPL and MSLD calculations, Semarang city has a lower value (225.41 and 181.98) than Bandung and Malang. This is indicated by the longer path distance found on the Semarang city map compared to Bandung and Malang. Furthermore, comparative deviations in angular Depth and the distance of the path comparing Amsterdam and Delft cities with Bandung, Semarang and Malang can be seen in *Table 8* and *Table 9*.

Table 8 shows that Bandung and Malang have the lowest deviations (0.54 and 0.75) with Amsterdam compared to Semarang. As for Bandung, the city of Semarang and the city of Malang have the same relative deviations as the city of Delft. Overall, especially in the calculation of ASD and MSSPA, Bandung, Semarang and Malang have lower deviations than Delft. Conversely, in other words, if seen from the deviation in the calculation of MSSPA, MSSPL, and MSLD, the city of Semarang and the city of Malang have a low deviation to the city of Delft (*Table 9*).

Table 8. Deviation with Amsterdam

Cities	ASD	MSSPA	MSSPL	MSLD
Bandung	0.54	3.46	82,458.97	52,196.29
Semarang	1.46	4.05	112,713.24	79,649.23
Malang	0.75	3.08	110,956.32	77,961.71

Table 9. Deviation with Delft

Cities	ASD	MSSPA	MSSPL	MSLD
Bandung	4.51	7.35	26,452.45	26,461.75
Semarang	3.59	7.94	3,801.81	991.19
Malang	4.30	6.97	2,044.89	696.32

5. DISCUSSION

The results show significant similarities in the master plan pattern of the colonial city planned by Herman Thomas Karsten. This method uses a quantitative approach that looks at the similarities of the statistical data produced by the DepthMap program, but it can illustrate how far the similarities of colonial cities in Indonesia are to its parent city in the Netherlands. The method used in this similarity analysis will offer a faster and easier way without making direct observations and surveys, such as asking all respondents who usually need more time to accumulate data. Instead, a similarity study can be conducted by using map image data and digitising images.

There are other methods carried out such as those carried out by Go and Lai (2019), which hold a study of historic colonial buildings in the period of the Dutch colonisation, however, they did not calculate how similar the buildings in their parent cities were by calculating using the space syntax approach. Moreover, whilst other research applies space syntax concerning city morphology (Amorim, Barros Filho, & Cruz, 2014; Brad et al., 2016), and Filomena et al. (2019) have done computerised calculations, to enrich the study of syntax space, this analysis has been done by calculating Depth and Connectivity on the master plan of a city.

Since the calculation is done only based on physical images, then the morphology of Indonesia's colonial cities and the parent city in the Netherlands will look very dissimilar. When a study does not apply syntax space, it could be considered dissimilar in its hierarchy. By applying this method, a significant similarity among these cities could be found by reason that the calculation is using VSD and Connectivity. By obtaining the pattern of Depth and Connectivity in the Dutch colonial city in Indonesia, it will be possible to determine which part of the city should be considered if urban development is carried out. If there is no guideline for this pattern, then urban development will spread without any clear guidelines. This would be difficult for as long as study uses a manual calculation approach with many human errors.

6. CONCLUSION

The results demonstrate that significant similarities exist in the master plans of cities in both countries. It has been observed that the planning of Herman Thomas Karsten was likely to follow that of Amsterdam instead of Delft. Since measured based on the similarity ratio, then Depth and Connectivity are regarded as the basic things that result in the pattern of Indonesia's colonial cities being resemblant of the pattern of cities situated in the Netherlands (even though physically they incline towards looking different), since this study specifically concentrates on the justified graphs. This method will enrich the study of space syntax in the development of a colonial city and assist urban planners and city governments in determining policies for urban development.

For future research, it would be helpful to design a simulation that allows depth analysis. Furthermore, it is important to evaluate other Indonesian colonial cities and those situated in other countries. This allows planners and the city government to identify deviation of the development of a city by comparing it with its original model, which offers a basis to establish sustainable planning directives comparable with sustainable urban form.

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