Tracing potential CBD land uses along roads in historic areas: A study of space syntax using isovist and connectivity attributes along Kayutangan street Malang, Indonesia

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Tracing potential CBD land uses along roads in historic areas: A study of space syntax using isovist and connectivity attributes along Kayutangan street Malang, Indonesia

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ABSTRACT

Urban sustainability is an interesting discussion on every development concept in all cities in the world. The issue in urban development that is the focus in several cities is sustainable urban form. Every urban development pays attention to the distribution of land use, which will affect the city's sustainability. One of them is related to an area in the city that has a particular historical value. This study examines the relationship between connectivity and visuals in specific road segments with historical significance. Connectivity is measured using a space syntax approach associated with isovist studies as visual analysis. The study location is along Jalan Kayutangan in Malang, Indonesia, with a high historical value as a Dutch colonial area. The determination of the isovist study is carried out at specific points along the Kayutangan road, then measured using DepthMapX, a spatial syntax tool to calculate spatial syntactic attributes. The results of this study are expected to assist in determining the best potential for the CBD area along roads that have historical value. It is hoped that this study will help preserve historical buildings and road corridors so that a sustainable city form can be achieved by understanding the potential of spaces along roads that have historical value.

Keywords : Connectivity; Historic area; Isovist; Space syntax; Sustainable urban form

1. INTRODUCTION

Urban development needs to maintain the characteristics of the city to stay awake. Every action must pay attention to the master plan by considering the land use zone (LUZ) set out in the master plan (Tutuko & Shen, 2016). Urban patterns are very helpful in controlling the development of cities with historical value (Bonifacius et al., 2021; Tutuko et al., 2019, 2021). Indonesia has been a country associated with the Dutch colonial state for approximately 350 years, affecting the patterns of cities in Indonesia. They wanted to build the same city as in the Netherlands. Therefore the architecture of buildings in colonial cities is very similar to building construction in the Netherlands (Coté, 2014; Roosmalen, 2000). Several studies on historical cities, such as colonial city studies with participatory, political, and economic approaches (Agrawal, 2010; Rodríguez-Alegría et al., 2013; Yi & Ryu, 2015). In certain areas, especially in the central area of the business and trade district (CBD), which is the center of city growth, it is necessary to re-examine the potential for city development in the present. Sustainable development requires a study of the city's shape that is achieved to obtain a Sustainable City Shape. It is necessary to study the potential of LUZ in the CBD, which has historical value.

Several studies on the study of urban patterns have been carried out by various studies, namely a study of comparative comparisons between colonial Indonesia in Indonesia and the countries that colonized it using a depth approach (Tutuko et al., 2019, 2021). in a Justified Graph which is usually done to define a hierarchy of relationships in a syntactic space. This study on spatial analysis also discusses the spatial structure of an area and urban area to obtain connectivity and depth from the arrangement of zones in the city (Agirbas, 2019; Kohsaka & Uchiyama, 2017; A. Penn et al., 1998; Alan Penn, 2001; Prasertsubpakij & Nitivattananon, 2012). Based on previous studies, this method will be used to continue previous research related to the pattern of development of a city, especially cities that have historical value.

Further studies are needed to calculate important zones in urban land use that have historical value in their LUZ. The method used is to know the spatial syntax in the CBD area, which has a historical significance focused on observing the road corridors along the area. Then a visual search is carried out at specific observation points, which are the beginning of the human movement that will pass through the road. An isovist study is needed to understand a two-dimensional view of the observed path. Furthermore, it will be correlated with the connectivity that occurs on the road, represented in a line. Calculations are carried out using DepthMapX, which is a space syntax tool for calculating connectivity. The master plan data is calculated for connectivity, and an isovist analysis is performed. This study aims to find the best potential by calculating connectivity and visuals in the central business district (CBD) zone, which has historical value. The CBD zone was chosen because it is an area that should have a lot of connectivity and be connected to other zones; besides that, this area has high development potential. The approach is carried out by analyzing the suitability between the road pattern and the spatial configuration pattern of the historic city by using spatial syntactic attributes (isovist and connectivity). The goal is to enrich the scientific treasures in the science of spatial syntax on certain roads that have historical value. This study will also help designers, planners, and policymakers in the city find out the condition of urban planning in urban land uses with historical value.

2. LITERATURE REVIEW

Land Use Zoning

It is expected that the city government needs a tool that can know and control its urban development, namely land-use zoning (LUZ), to manage the provision of land and buildings (Mark & Goldberg, 1986). LUZ also helps control urban sprawl. Several discussions on urban sprawl discussed land use in cities that have an impact on the environment, such as land degradation, ecological issues, and financing (Aguilar & Santos, 2011; Gennaio et al., 2009; Lestrelin, 2010; Nellis & Maca, 1986; Poelmans & Van Rompaey, 2009; Saint-Macary et al., 2010; Zhang, 2001; Zhao, 2010; Zhong et al., 2011). In this study, LUZ becomes a necessary variable as a basis for determining the part of the city area that has particular potential, in this case, those that have office and trade functions located in the CBD zone that have particular historical values.

City Development in Malang City

Malang is the second-largest city in the province of East Java. This city is included in the Dutch design by an architect named Herman Thomas Karsten (Coté, 2014; Roosmalen, 2000). At that time, the development of the city of Malang was marked by the expansion of transportation modes and inter-city routes to the north of Malang (Malang-Pasuruan-Surabaya) in the 1880s (Hadinoto, 1996; Roosmalen, 2000; Subadyo et al., 2018). The city of Malang has the character of a historical colonial Dutch town with several development phases. At that time, the city's development required renewal/reformation of the city structure by the Dutch government. The city's action needed to be evaluated and controlled to maintain its sustainability (Subadyo et al., 2018).

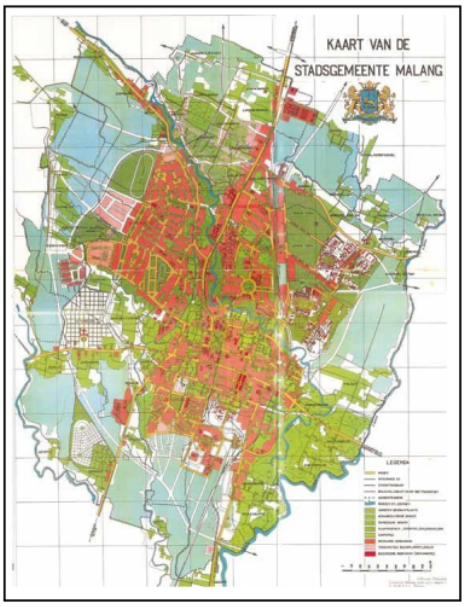

Figure 1. Malang: city map (1937) (Roosmalen, 2000)

The city of Malang in 1937 (figure 1) had a relatively complete city master plan to meet the city's needs at that time. The master plan shows that the city of Malang has a high historical value in urban planning, which is supported by documents on the stages of colonial city development. Based on this map, calculations can be made on LUZ in the office zone, trade zone, and residential zone.

Figure 2. Malang: intersection Kajoetangan-Smeroweg (1937) • 'A striking example of the proper functioning of similar architecture around an (extended) (Roosmalen, 2000)

A solid colonial-style building in the Kayutangan street area with a North-South axis and a West-East axis facing Mount Kawi shows that the Dutch well planned it (figure 2). In colonial urban planning in Indonesia, Malang City is a highland city between the mountains of Semeru and Kawi. The city is developing with the existence of coffee and sugar plantations and a railway line that transports these plantations. In 1900 and 1925, the city of Malang was the city with the fastest population in the Dutch East Indies. To accommodate this growth, the city was expanded mainly towards the North (Roosmalen, 2000). Thomas Karsten planned the development of the city of Malang in 1933 with complete details on land use zones. This plan is made in detail from land use,

building types, roads, rail routes, trams, water pipes, public parks, and cemeteries, as shown in the city master plan (figure 3).

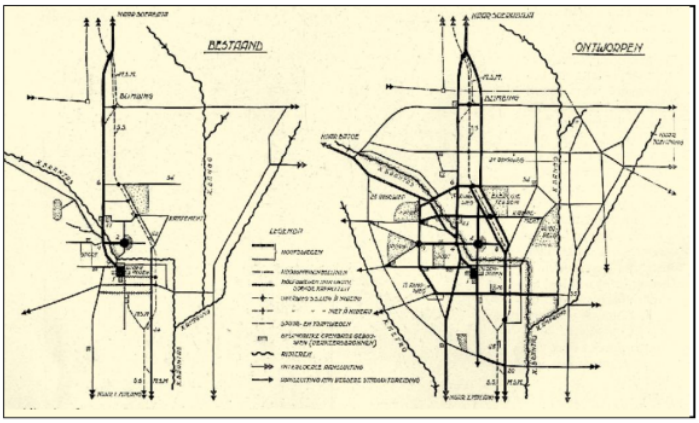

Figure 3. Main roads diagram (Left: situation before 1929; Right: design from the supplemented overview plan of 1935) Design: Ir H.Th. Karsten (Roosmalen, 2000)

Sustainable Urban Forms

A sustainable city has a relationship between the shape of the city and the scope of city elements according to its geographical conditions. If urban sprawl is not considered, it will create problems for the city, such as moving urban residents to sub-urban areas that have more land and are cheaper (Gibbins, 2001). To reduce this issue, city development must pay attention to the form of a sustainable city by considering the part of the city that must be maintained. In the research, it is the arrangement of areas that have Dutch colonial historical values.

Space Syntax

Space Syntax is a graphical theory used by architects to examine how the spatial structure of buildings and cities affects the economic, social, and environmental outcomes of human movements and social interaction (Dawson, 2002). The space syntax method can be used in city space reading. This method was developed by a research team led by Bill Hillier and Julienne Hanson at Bartlett School of Architecture and Planning, University College London in the late 1970s and early 1980s, to read urban space (Hillier & Hanson, 1984). The syntax space method proves helpful in reading objective space, also stating a relationship between physical structure and social structure. Using this method, the operation of the urban system can be read to building structures (Önder & Gigi, 2010). Space Syntax is the theory and technique associated with the relationship between the complex spatial structure and the human being (R. C. Dalton & Dalton, 2007).

The study of space syntax focuses on city development by combining geometric and geographic accessibility analysis by the accessibility of existing transportation modes in the city. As a network, it can be approached on a city's geometric patterns and geographical conditions (Law et al., 2012). Space syntax encompasses a set of theories and analytical, quantitative, and descriptive tools for analyzing spatial formations at different scales: cities, buildings, and interior spaces (R. Dalton, 2005; Hillier, 2007; Hillier & Hanson, 1984). Another study stated that Space syntax focuses on lines (e.g., streets, passages) and provides an excellent guide to evaluate a space layout

(Batty, 2004). In the urban context, this is influenced by human movement and social interaction (Dawson, 2002). The space syntax method can be used in reading city space (Hillier, 2007) and is helpful to read objective space, also stating that there is a relationship between physical structure and social structure. This approach can be applied to large-scale urban areas and complex settlements and buildings.

3. METHODS

The approach will conduct the calculation of the connectivity and isovist on Kayutangan street in Malang city, known to have been planned by Herman Thomas Karsten (Bogaers, 1983). Previous research conducted using Justified Graphs to calculate colonial city patterns in Indonesia was the basis for developing this study. That study found significant similarities between the master plans of cities in Indonesia and parent cities. In the point of view of the similarity ratio, then Depth and Connectivity is the essential thing that caused the pattern of colonial cities in Indonesia to be similar to the design of cities in the Netherlands (although physically they tend to look different) because this study focused specifically on the Justified Graphs (Bonifacius et al., 2021; Tutuko et al., 2019, 2021). Furthermore, to add to the knowledge of space syntax in developing urban patterns towards a sustainable urban form, a study was conducted on a road segment with historical value in the CBD area in the city of Malang.

Isovist Approach

The method for visually understanding a space in this study uses isovist. The isovist is the set of all points visible from a certain point of view in space and concerning the environment. According to the position, when the isovist point is placed, the shape and size of the isovist can change. This isovist creates a set of isovist scalar fields that form an alternative description of the environment. This method is compatible with the study of behavior and perception in architecture, especially in display control (Benedikt, 1979). Using an isovist study, visuals will be obtained from several points along Jalan Kayutangan. Those good potentials will be seen in the function of existing buildings throughout the CBD area.

The first step is to calculate the imported map from DXF format into DepthMapX to produce an axial map. The built environment axial map is a collection of the most extended and fewest axial lines. Axial maps can have different resolutions: low, medium, or high. The Axial map is then converted to a segment map by limiting the distance of 200 meters, 400 meters, and 800 meters, based on walkability distances for pedestrians (Larsen et al., 2010; Olszewski & Wibowo, 2005). Connectivity is the number of connections each road has to directly neighbouring streets, and that a road with many links will have a high connectivity value (Yamu et al., 2021). Axial integration (HH) measures the degree of accessibility to all other roads in the system (Hillier & Hanson, 1984; Yamu et al., 2021).

4. RESULTS

The study location is an area well known as a representation of architectural developments during the Dutch period, especially for office buildings and trade. This area extends from north to south and ends at the city square of Malang. At that time, this area became a meeting place for residents of residential regions in the West and East, so the connecting roads were strategic routes (figure 4).

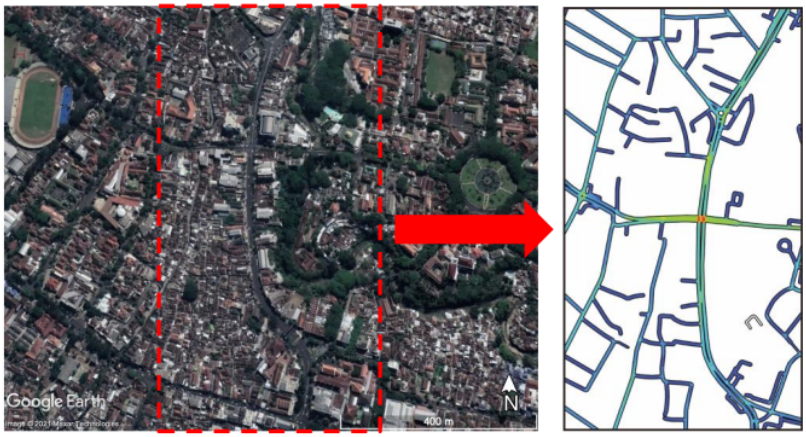

Figure 3. Aerial view of study location (Left) and Visual Graphic Analysis (VGA) on Kayutangan road (Right)

Based on the calculation steps using the DepthMapX software, an image with DXF format is run to get the Visual Graphic Analysis (VGA) results. VGA shows that the best connectivity is at the intersection between Kayutangan and Semeru roads. The higher the connectivity is shown in red. While the yellow and orange colors are along the Kayutangan road, indicating that this road is sufficient to function as a gathering place because it is close to a line with high connectivity (figure 3 (Right)).

Figure 4. Connectivity line (Left) and Integration (HH) line (Right) (Source: DepthMap Calculation)

The following calculation converts the VGA map into an axial line map to get lines that represent human movement on the road. The calculation results (Figure 4 Left) show that the highest connectivity is at the North end (Avia intersection). This point is the end of the decisive movement from various points that will lead to the Kayutangan area. Meanwhile, the highest line of integration (HH) is along Kayutangan street in the north-south part and spreads west-east. This line of integration (HH) shows that Kayutangan street is a road with lines that are interconnected with other lines with high connectivity.

Figure 5. Connectivity on the segment on Kayutangan road (Left) and Integration on segment (Right) (Source: DepthMap Calculation)

After calculating the line, proceed with converting the map to a segment map. This calculation is carried out to obtain the line segments contained in Kayutangan street. The highest segment connectivity is along Kayutangan street and road branches (figure 5 Left). In contrast, the highest integration segment is in the center of Kayutangan street (figure 5 Right).

Table 1. Calculation of connectivity and integration on lines and segments in the Kayutangan street area.

No	Attributes	Total	Minimum	Maximum	Average
1	Connectivity	137	0	12	3.75
2	Integration (HH)	131	0	1.61	0.97
3	Connectivity (segment)	774	3	6	4.82
4	Integration (segment)	774	5.46	388.04	247.96

The analysis results on the space syntax attributes show that the total connectivity and integration (HH) on Kayutangan Streets is 137 and 131. Meanwhile, the attributes of the line segment calculation offer the same value (774). This figure shows a good correlation between connectivity and integration on Kayutangan Street (Table 1).

Figure 6. Calculation of the line segment integration at 200 m, 400 m, and 800 m. (Source: DepthMap Calculation)

The following calculation is to perform segment analysis by categorizing it into three distances, namely 200m, 400m, and 800m. This analysis was conducted to obtain the best road segment for pedestrians in the three distance ranges. The best in the 200m road segment is on the north side, while at 400m, the highest is at the center of the intersection and along the north and south evenly. As for the 800m distance has expanded to the West and East sides of Kayutangan street (Figure 6).

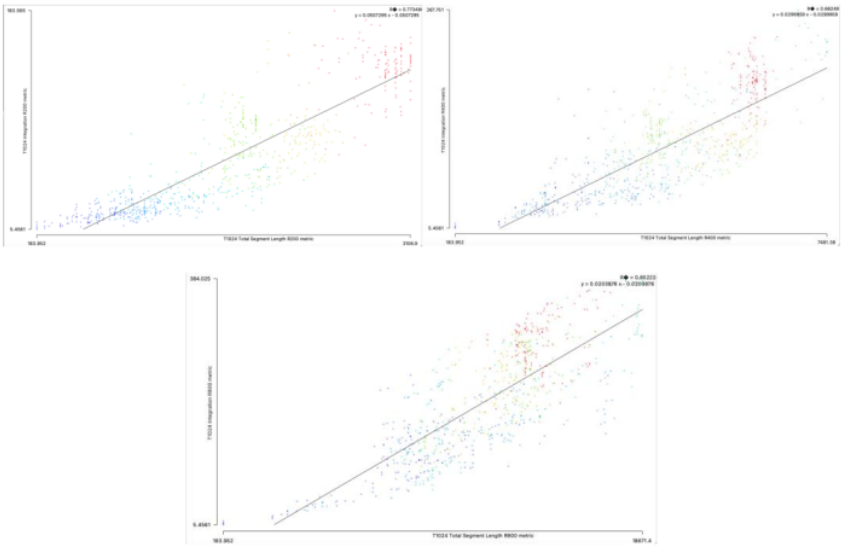

Figure 7. Scatter plot of the relationship between the line of integration and the length of the segment at a distance of 200m, 400m, and 800m. (Source: DepthMap Calculation)

Based on the scatter plot between segment integration and total segment, there is a good correlation with a few external factors trend. The 200m line segment has a value of $R^2 = 0.77$; the 400m line segment has a value. $R^2 = 0.66$, and the 800m line segment has a value of $R2 = 0.65$. This indicates that the longer the segment, the greater the influence outside the trend line, which may be due to line connectivity outside Kasan Kayutangan street (figure 7).

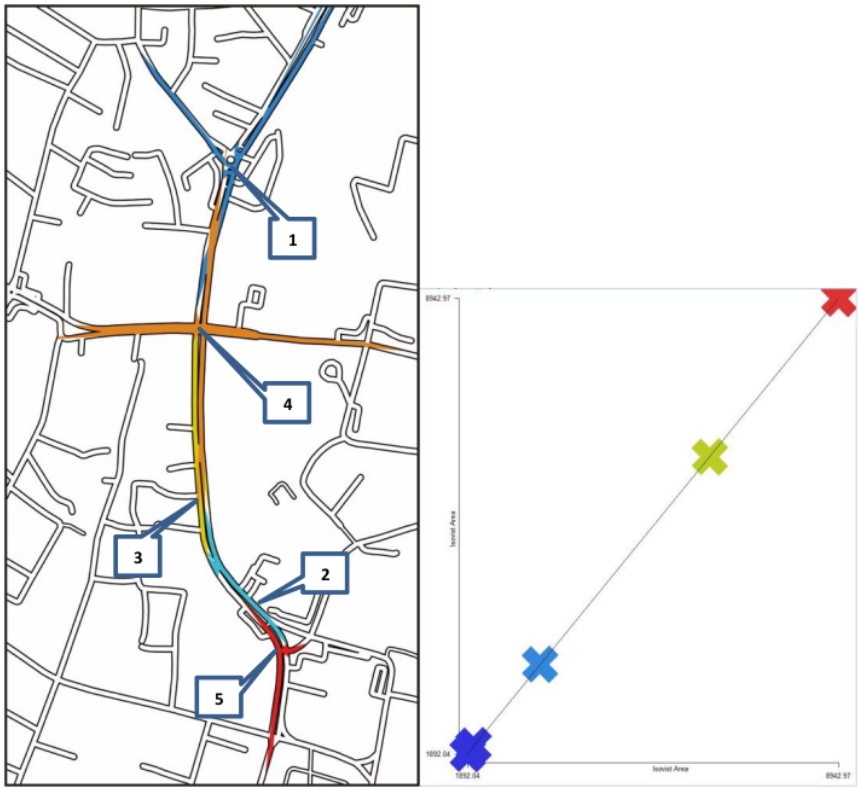

Figure 8. isovist at 5 points along Kayutangan street (Source: DepthMap Calculation)

Furthermore, to get a visual of the highest area in the Kayutangan street area, an analysis is carried out at 5 points along the road. This point is determined based on the best position that can be seen on a particular side of the road. The scatter plot shows that the red one has the most expansive area (figure 8).

Tabel 2. The isovist area at each point along Kayutangan street.

No	Isovist	Isovist Area
1	1	6491.56
2	2	1892.04
3	3	3269.74
4	4	8942.97
5	5	2013.41

Table 2 shows that point 4, in the center of Kayutangan street, has the highest area value (8942.97). The lowest isovist area is point 2 (1892.04), which is on the south side. In isovist analysis, it is possible to determine the location of the road in which part has the best visual capture area along Kayutangan street.

5. DISCUSSION

Figure 9. Agent analysis at 2 points on North and South Kayutangan street (Source: DepthMap Calculation).

Agent analysis at 2 points on North and South Kayutangan street. Agents are released by entering 1 million steps and 500 agents in this simulation. The simulation shows that the Southside has a broader area for agents to gather than the point on the Northside Figure 9). Figures show that the length of the segment affects the potential for agents to pick in a road segment. It can be said that the possibility to place the best function is on the south side of the Kayutangan street area.

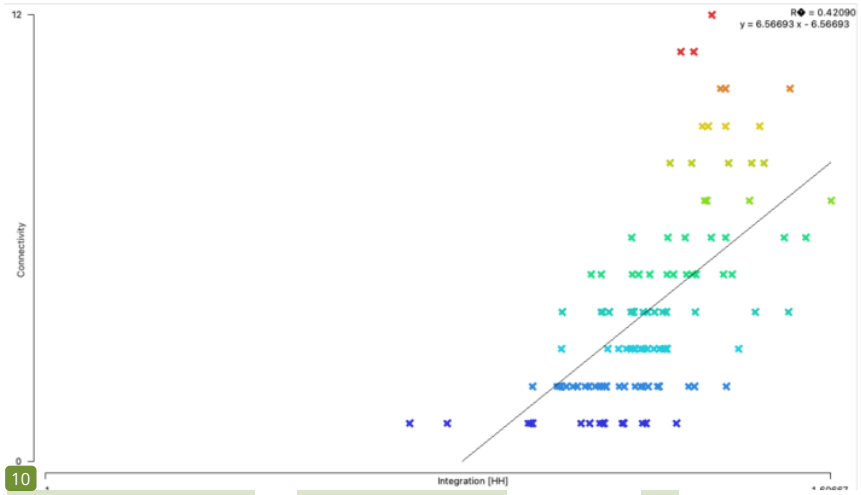

Figure 10. Scatter plot of the relationship between Connectivity and Integration (HH)

Figure 11. Scatter plot of the relationship between Isovist and Connectivity

Figure 10 shows the correlation with a value of $R^2 = 0.44$, indicating an influence outside the current trend. The result is different from what was achieved by previous researchers. Connectivity shows the number of connections that each line has with other lines, so roads with many connections will have a high connectivity value (Yamu et al., 2021). Meanwhile, Axial Integration (HH) is a measure of the level of accessibility to all other lines in the system (Hillier & Hanson, 1984; Yamu et al., 2021). While the discussion about isovist which is indeed an important thing in studying visual capture areas, then based on the scatter plot (figure 11) there is a good correlation with connectivity with a value of $R^2 = 0.99$. This figure shows a close relationship with the few influencing factors that occur in the Kayutangan street area.

6. CONCLUSION

The historical area has an important role in the development of a city. This can be proven by calculations using the space syntax. Determination of road bends and line intersections in the form of crossroads or junctions has the purpose of being connected to other locations in an urban network. From the results and discussion of the potential contained in the Kayutangan street area, it has a good value at several points as an appropriate location for gathering people. The isovist study shows that it has excellent potential to lay out a more strategic or attractive function at some point. At the same time, the road segment analysis shows suitable locations for pedestrians in each road segment. The conclusion about the initial catch point is better on the Southside to collect humans than the Northside, which is influenced by the length of the Kayutangan street segment.

The Kayutangan Street CBD area is an area that has high connectivity and integration. Interventions in mobility networks can affect socio-economic life in urban areas. This study will specifically assist in determining walkability in the area and potential functions in the road segment in the Kayutangan street area. Urban planners and policymakers will be assisted with isovist analysis and connectivity in regions with historical value.

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