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ANALYSIS OF INTELLIGIBILITY AND CONNECTIVITY-INTEGRATION RELATIONSHIPS IN THE CANGGU VILLAGE SPACE NETWORK BASED ON SPACE SYNTAX

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Abstract

Canggu Village, located in Badung Regency, Bali, is a popular tourist destination known for its beach and nightlife, which has led to rapid tourism development. This growth has both positive and negative impacts, including traffic congestion and uncontrolled construction. To address these issues, this study analyzes the spatial planning of Canggu Village, focusing on accessibility, connectivity, interaction, and intelligibility. The aim of this analysis is to be able to produce output values for aspects of the level of effectiveness of spatial planning which in the future can be used as a reference for providing recommendations for more appropriate village tourism development so that tourism development and community residential needs can still stand side by side. Using a quantitative-experimental approach and Space Syntax analysis via the DepthmapX application, the research finds: (a) low to moderate local connectivity (average 2.46) with limited intersections; (b) relatively low local integration (mean 1.04), requiring more effort for movement; (c) high intelligibility (R^2 = 0.87722), allowing effective navigation; and (d) numerous minor roads emerging from major routes, creating an accessible spatial structure. This raises questions about the factors influencing connectivity amid unplanned development. Suggested development plan according to research results are: 1) Improving Connectivity in Local Areas (intersection/direct routes); 2) Boosting Integration Between Tourism Zones; 3) Optimizing navigation; 4) Tourism Supporting Infrastructure Development; 5) Involvement of Technology and Smart Tourism.

Keywords: Tourism, Spatial, Space Syntax

1. INTRODUCTION

The tourism sector is the sector that contributes the largest income to the province of Bali. In reality, the main income of the Bali Province is in the tourism sector. It is known from statistical data that foreign tourist visits to Bali in the last 4 years have continued to increase. This sector is capable of creating millions of livelihoods for local communities, either through direct employment or through the sale of goods and services. Canggu Village, as one of the village areas in Bali which has a high level of tourism popularity, also enjoys many tourist visits to its area. Canggu Village has become popular

because it has many tourist attractions, so many tourists choose to spend their holidays in Canggu Village (Qothtrunnada, 2023).

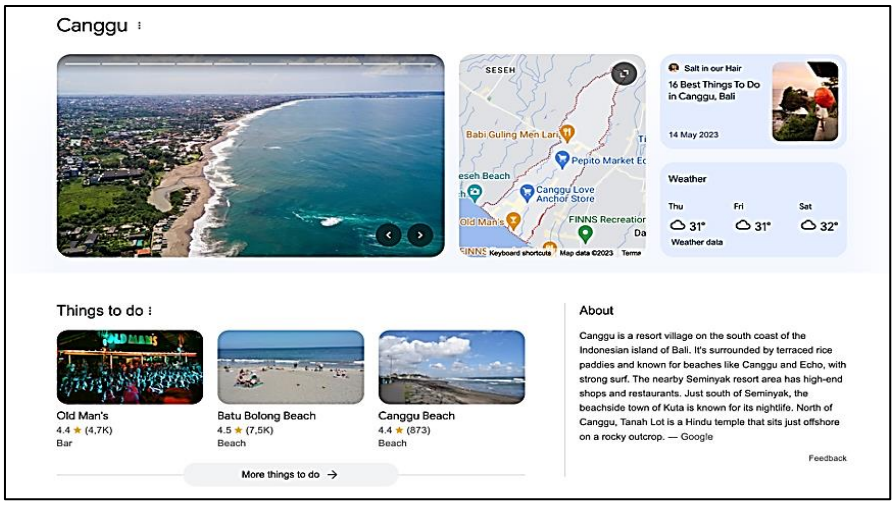


Figure 1. Map of Locations and Popular Tourism Destinations in Canggu Village
Source: Google Image Search (Desember, 2023)

Canggu Village, with its popularity, also apparently has several important problem points that need to be underlined based on the results of research by researchers from ITB (Bandung Institute of Technology), namely Ir. Tubagus, Hafsah, and Titan. Some of these points are: 1) There has been a change in land use from rice fields to built-up areas, and this change has intensified after 2019; 2) The increasing tourism activity causes a reduction in mutual cooperation in society; 3) Traditional art in Canggu Village is still preserved and preserved, however, increasing crime and traffic jams are problems that need to be overcome (Nurul Annafi, 2023). These problems arise as a result of the Land Use Transformation Phenomenon which is influenced by the development of aspects of the surrounding built environment, including local community settlements as residential areas supporting tourism (Widhijanto & Tisnaningtyas, 2018).

Figure 2. Overview of Spatial Planning Issues that occur in the Canggu Village Area
Source: Google Image Search (Desember, 2023)

The problems summarized are closely related to the current (existing) aspects of village spatial planning which have been impacted by tourism developments from year to year. In the future, related to the continuous development of tourism in Bali, especially Canggu Village, Canggu Village needs to formulate optimal and efficient development where development must be able to accommodate residential needs and also tourism needs that continue to grow. The Development Formula can be prepared by first carrying out a Space Syntax-based spatial planning study to analyze the level of accessibility, connectivity, interaction and intelligibility of the current Canggu village spatial plan. The findings are analyzed and aligned to find out what characteristics of the spatial configuration are formed (morphology). The big hope of this study is of course to be able to find problem points in the existing spatial planning so that in the future we can formulate solutions in the form of spatial development plans that are able to solve existing problems. From these characteristics, in the future, it can be continued with the preparation of Village Spatial Development Recommendations which can be proposed to the Village as Design Guidelines for Spatial Planning for the Tourism Responsive Canggu Village. Based on the background facts and phenomena of tourism development in Canggu Village, optimal future tourism development planning is of course very necessary, so answers to the following research questions are existed : What is the current level of accessibility, connectivity, interaction and spatial intelligibility of Canggu Village as an impact of tourism development?; This research purposes is to find the value of the level of accessibility, connectivity, interaction and spatial intelligibility of Canggu Village and use it as a reference for recommendations for the development of the Canggu Tourism Responsive Village in the future.

2. LITERATURE REVIEW

2.1 Spatial Configuration

The organization and planning of space in a village, referred to as village spatial configuration, focuses on optimizing the management of natural resources, infrastructure, and services. This comprehensive process encompasses various aspects, including the physical layout of the village, territorial organization, allocation of natural resources, infrastructure planning, spatial arrangements, and the coordination of social and economic services. The primary objective of village spatial configuration is to maximize the efficient and effective utilization of available resources, infrastructure, and services within the village context. Efficient spatial configuration can be achieved through effective residential spatial planning. The efficiency of spatial configuration is closely associated with aspects of Connectivity, Integration, and Intelligence. Connectivity primarily assesses spatial configuration solely in spaces that are directly connected to each other within a given configuration (Sarma, 2006).

Basically connectivity measures how many roads are connected to the observed road. Connectivity is used to determine the level of interaction of each space with spaces that are near that space. The main function of values is to measure the level of intelligence. Calculate the connectivity value by adding up all the rooms that are directly connected to the observation room. Integration is measuring the configuration from each original space to other spaces in a system. In general, it quantifies how close the observation space is to all other spaces and can be seen as a measure of relative asymmetry (Hillier & Hanson, 1984). Integration basically measures how integrated a road (or center) is in the network. Integration can be considered to represent the potential of a destination. The more space that is connected to the observation space, the higher the integration value. Good

connectivity and integration of the space syntax can mean that an area is an area that has good accessibility and is easy to reach most of the time (Ramadhan et al., 2018). The high accessibility of this area makes it suitable for establishing social or public facilities, as it holds significant potential for attractions and destinations. In space syntax, intelligibility is the most comprehensive measurement. It reflects the relationship between local-scale measurements (connectivity) and global-scale measurements (integration). Therefore, intelligibility assesses the structure of spatial configurations. Unlike connectivity and integration, intelligibility represents a property of the overall spatial system, whereas connectivity and integration are properties of individual spaces.

2.2 Space Syntax

To examine the accessibility, connectivity, interaction, and intelligibility aspects of the spatial layout in Canggu Village, a solid understanding of Space Syntax is essential. Space Syntax is a spatial theory accompanied by a set of analytical tools, both quantitative and descriptive, used to analyze spatial formations in various contexts such as buildings, cities, interior spaces, or landscapes (Sarma, 2006). The primary objective of Space Syntax is to explore the connection between humans and the spaces they inhabit. It is based on the idea that certain human traits are embedded within spatial systems, and that these traits are conveyed through the space and its organization (Dursun, 2007). Space syntax highlights the relational nature of spatial configuration and how it shapes human behavior by conveying social information. Its goal is to develop strategies to design spaces that reveal their social meaning, leading to practical insights on how spatial layout influences social or cultural factors. The focus of space syntax research is understanding configured space and its social significance (Bafna, 2016). Space syntax is a tool for understanding space by analyzing its organization, movement patterns, and social meaning. It views space as dynamic and experienced by its occupants. The DepthMapX application (space syntax app) simplifies space syntax analysis, making it easier to interpret, and can be used to study individual movement within circulation patterns.

3. RESEARCH METHODS

The choice of appropriate methods greatly impacts the accuracy of research results. To find the right method, it's essential to first define the problem and review relevant literature. This study uses a quantitative approach based on measurable simulations, making it experimental (Groat & Wang, 2013). The Canggu Village Area was designated as a case study in this research to examine the optimality of circulation, interaction and connection between residential areas and village tourist destinations based on spatial configuration tests. This experimental study combines connectivity and integration with existing residential circulation patterns. Using simulations, the researcher proposed a plan and tested a problem-solving planning model (Prasasti Barada & Mutiari, 2013). This quantitative-eksperimental methods done in 4 (four) steps: 1) Survey & Simulation; 2) Data Tabulation; 3) Simulation Based Analysis; and 4) Research Conclusions. For this research there were 2 datasets: 1) Primary Data (tracing, mapping, surveys); and 2) Secondary Data (journals, books, etc.). Data collection were done by observation, mapping/tracing, documentation. Space Syntax is a way to analyze the relationship between spatial configuration and humans as users of space, both on a small scale and in urban areas. Space Syntax deals with the relationship between spatial configurations and people in a scalable way, using graphical and mathematical language (Lesmana, 2022). This research utilizes Space Syntax analysis with the help of

DepthMapX software to study individual movement in circulation. The analyses available in DepthMapX include Axial Line, Convex Space, Visibility Graph, and Agent Analysis (Sa'diyah et al., 2019). Especially for this research, Axial Line Analysis were used for a better understanding on complex spatial structure in Canggu Village area. Space syntax analysis has 3 indicators of analysis results, namely: connectivity, integrity and intelligibility. In DepthMapX, assessment indicators are needed to measure space configuration analysis. It uses the visual area method, with gradient colors indicating parameter values. Dark blue represents the lowest value, while red indicates the highest. Space syntax analysis reveals key insights into urban spatial structure and human behavior, identifying patterns that link spatial configurations to human activities (Liu et al., 2015). It explores scales from buildings to entire cities (Khairanisa, 2022)., and while it doesn't capture individual motivations, it explains much of the variation in aggregate human movement (Penn, 2003)**.** This method is a powerful tool for understanding urban space dynamics, providing a quantitative foundation for urban planning, design, and research.

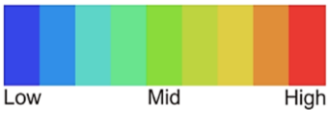


Figure 3. Gradation Color Parameters in Space Syntax Analysis on Application DepthMapX
Source: Google Image Search (Desember, 2023)

4. FINDINGS AND DISCUSSION

Before conducting space syntax analysis, a base map in .dxf format is needed, compatible with DepthmapX software. This map is created using Cadmapper, followed by manual adjustments in AutoCAD to reflect field conditions. The spatial mapping of Canggu Village shows a high density, with a total area of 5.23 km². Of this, 2.43 km² (46.48%) has been developed, while 53.52% remains undeveloped, consisting of gardens, rice fields, and vacant land.

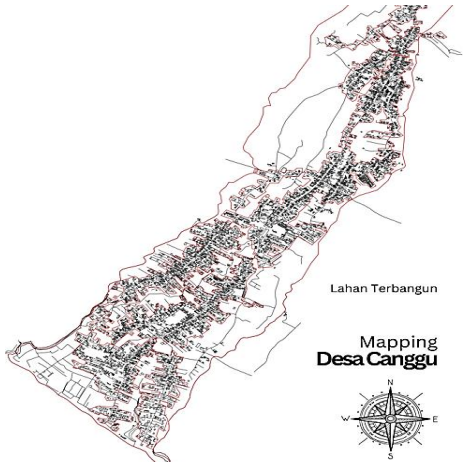


Figure 4. Mapping and Calculation of Built-up Land Area in Canggu Village
Source: Researcher (2024)

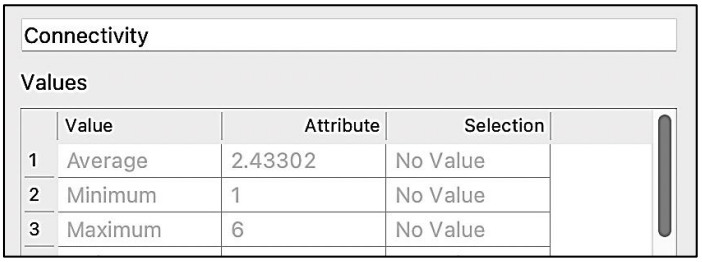
The 46,48% already developed area shows a complex linier spatial structure of Canggu Village mapping that based on the structure of the street/road line (mayor and minor). With this mapping, a further stage, namely the axial space syntax analysis stage, can be carried out.

4.1 Space Syntax Analysis

Space syntax analysis for Canggu Village uses segment analysis due to its higher detail and sensitivity to local movement, making it ideal for residential areas with complex road networks and smaller spatial scales compared to city centers.

4.1.1 Axial Analysis on Space Connectivity Levels

Axial analysis of Canggu Village examines spatial connectivity between buildings to identify points with high, medium, or low connectivity. The average connectivity score is 2.43 out of 6, indicating a "Low" level of connectivity overall. Many minor circulation routes, classified as private access, are not interconnected, making spatial connectivity challenging.


Connectivity

Values

	Value	Attribute	Selection
1	Average	2.43302	No Value
2	Minimum	1	No Value
3	Maximum	6	No Value

Figure 5. Results of Axial Analysis of Spatial Connectivity Levels in Canggu Village
Source: Researcher (2024)

In axial line-based space syntax analysis, connectivity is a parameter that shows the number of direct connections (intersections or deviations) that an axial line has with other axial lines. In this context, the connectivity value reflects how many road sections or paths are directly connected to a road or space being analyzed. If in the analysis results the average connectivity value is 2.46, and the connectivity value is in the range 1-6, the following is the interpretation of the analysis results:

a. Average Connectivity Value 2.46

   In accordance with the previous discussion of the average value, the number 2.46 shows that on average each axial line (lane/road) in the network is directly connected to around 2 to 3 other segments/lanes. This means that these lines have a relatively low level of connectivity. In networks with low connectivity values, paths are often more isolated or do not have many direct connections with other paths.

b. Classified as Low Connectivity

   With values ranging from 1 to 6, the average of 2.46 is at the bottom of the connectivity spectrum. The paths or roads in this network tend to have few direct connections with other paths, indicating a more closed or separated road network. In settlements, a low connectivity value can mean that the streets or spaces are not directly connected, so movement between spaces may be more limited.

c. Low Connectivity Impact

   Mobility Limitations: Routes with low connectivity often do not support smooth or direct movement between places, so regarding tourism activities people need to travel longer distances or go through more intersections to reach their destination. And the roads are too private sometimes can causes confused in user movements. Impact on Social and Economic Activities: Low connectivity may reduce social interactions and economic flows in certain areas, as some places may be more difficult to reach. These more isolated areas may be less developed or socially and commercially inactive.

If the results of the axial analysis show that the average connectivity is 2.46, this indicates that the level of spatial connectivity in the network is relatively low. low level arises related to locals information regarding the construction of tourism facilities (homestays, inns, villas, cafes, restaurants, etc.) causes the opening of many new small roads which are not connected to each other. As a recommendation, improving connectivity could be considered, for example by designing a more integrated road layout or improving inter-space accessibility, so that it can support better mobility and improve social dynamics in the environment.

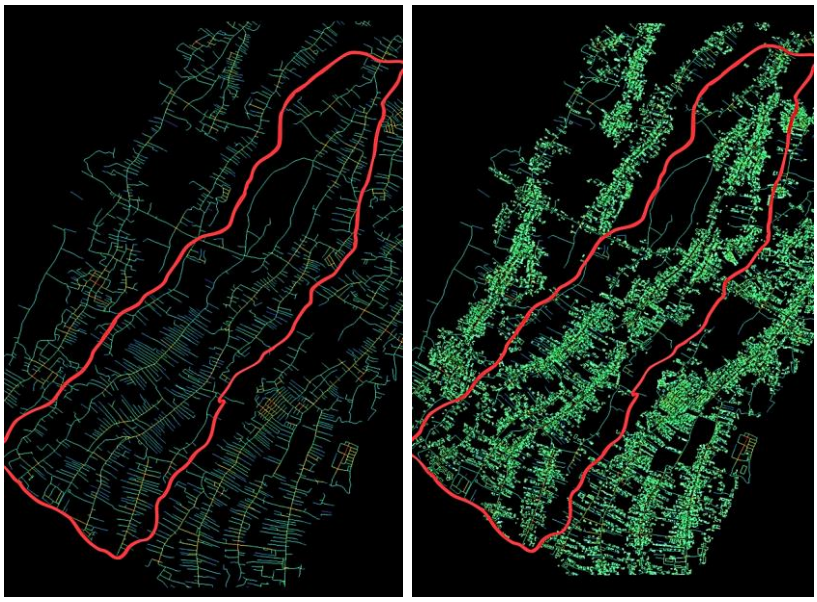


Figure 6. Axial Analysis Map of Spatial Connectivity Levels in Canggu Village Based on Major and Minor Road Lines and Building Blocks
Source: Researcher (2024)

4.1.2 Axial Analysis of Level of Space Integration (Integration [HH] 3)

In axial line-based space syntax analysis, the integration parameter [HH] (Hillier and Hanson integration) measures how easily a road segment can be reached from all other segments in the network. Integration [HH] 3 is usually used to analyze integration at the local level, with a radius that covers three steps or deviations from a particular segment. The analysis results of the average integration [HH] 3 value in Canggu Village are 1.04, and the range of values found in the network is between 1 and 2.06, so the interpretation of these results is as follows:

a. The average value of Integration [HH] 3 is 1.04

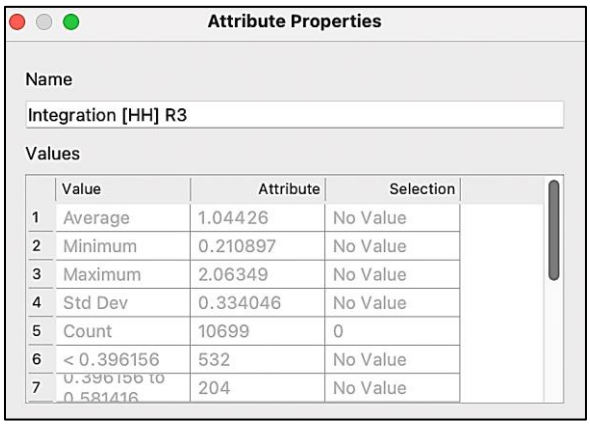
   A value of 1.04 indicates that the average level of integration in the analyzed road network is relatively low compared to the existing range. Integration [HH] measures how "integrated" or how accessible a segment is to other segments within a certain radius. The higher the value, the easier a segment is to connect to other parts of the road network.

b. Classified as Low Integration

   In the value range of 1 to 2.06, a value of 1.04 is at the bottom of the integration scale. This indicates that the segments in the network are less connected or require more steps (deviations) to be accessed from other segments in the network. With low integration, movement within a local radius (3 intersections) may be inefficient, because most roads or spaces are not directly connected to each other.

c. Implications of Low Integration

Local Accessibility Limitations: Paths or spaces in the network may be difficult to reach from one point to another within a short local radius. This could mean that movement within the residential area takes more time or requires a longer route. Low Potential for Social or Economic Activity: In residential contexts, low integration may indicate that areas may be more isolated and less connected to centers of social or commercial activity. This can influence social activities, interactions between residents, and local economic development.



	Value	Attribute	Selection
1	Average	1.04426	No Value
2	Minimum	0.210897	No Value
3	Maximum	2.06349	No Value
4	Std Dev	0.334046	No Value
5	Count	10699	0
6	< 0.396156	532	No Value
7	0.396156 to 0.581416	204	No Value

Figure 7. Results of Axial Analysis of Integration Level (Integration [HH] 3) of Space in Canggu Village
Source: Researcher (2024)

To improve integration in Canggu Village, redesigning the road network or adding more connecting roads can be considered. This would enhance mobility and improve the flow of people, fostering a more active social and economic environment. The current integration [HH] value of 1.04 (on a scale of 1-2.06) indicates low network integration, meaning local connectivity within a three-junction radius is suboptimal. To create a more connected and accessible area, increasing integration should be a priority.

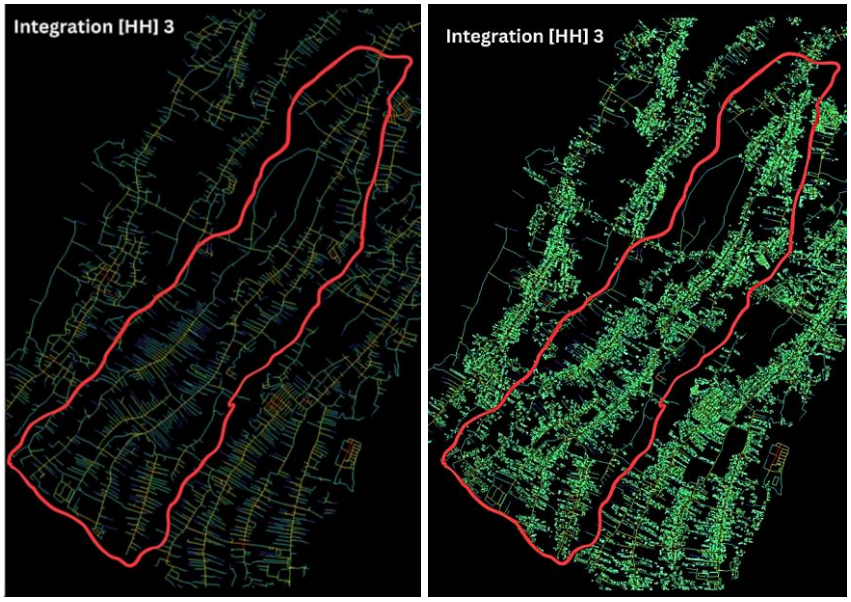


Figure 8. Axial Analysis Map of Integration Level (Integration [HH] 3) Space in Canggu Village Based on Major and Minor Road Lines and Building Blocks
Source: Researcher (2024)

4.1.3 Segment Analysis of Spatial Intelligibility Levels

Intelligibility in space syntax measures the relationship between connectivity and integration. Specifically, intelligibility assesses how well local connectivity can predict the level of global integration of a space network. In other words, intelligibility helps understand whether spatial networks that have high connectivity locally are also well integrated on a larger scale.

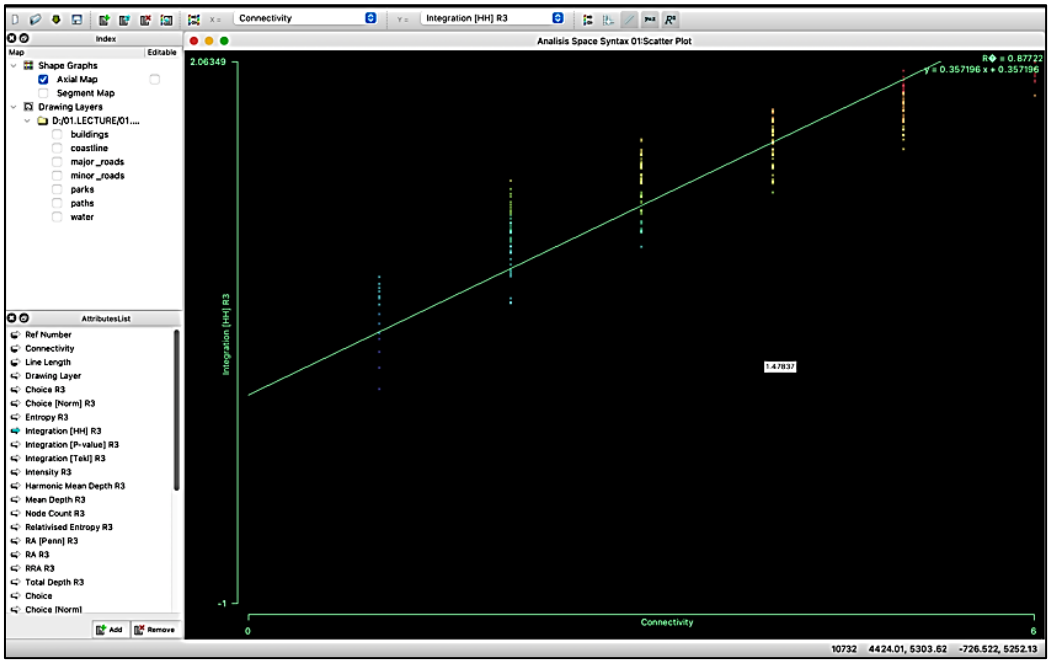


Figure 9. Axial Analysis of the Level of Clarity (Intelligibility) of Space in Canggu Village
Source: Researcher (2024)

After analyzing connectivity and integrity at the final stage, it is necessary to carry out an analysis of clarity or Intelligibility. Intelligibility analysis examines the relationship between connectivity levels and spatial integrity. A space becomes easier to recognize when it has a strong connection between these two variables (Setyaningrum et al., 2022). The degree of Intelligibility is determined by the correlation value (R2) which shows the reliability of the resulting regression model (Hillier, 2007). By plotting connectivity as the "x" variable and integration (Integration [HH] 3) as the "y" variable in the DepthmapX application, the correlation value R2 was obtained: 0.87722. This figure shows a "High" level of correlation, because it is close to the value "1". A high integrity value indicates that the spaces in the regional structure tend to be easily accessible (natural movement theory) (Hillier, 2007). In detail, the analysis of the Intelligibility diagram shows that the Visual Interpretation of Canggu Village Space Configuration based on axial line connection structures (Roads/Circulation) is as follows:

a. X-axis (Connectivity):

   Shows the connectivity value (number of direct deviations) which ranges from 0 to 6. So, in this network, each segment is on average connected to 1 to 6 other segments directly.

b. Y axis (Integration [HH] R3):

   Shows the integration value at a radius of 3 deviations. The highest value is around 2.06, and the lowest is around -1 (although in integration analysis usually negative values are rare, this may be related to scale adjustments or small anomalies).

c. R^2 Value (Intelligibility):

Located in the upper right corner with an R^2 value = 0.87722, which shows a strong correlation between connectivity and integration. An R^2 value close to 1 indicates that local connectivity is very good at predicting global integration, with most of the variation in integration being explained by connectivity.

d. Data Point Distribution:

The data points in the scatter plot appear to form a vertical pattern, with several groups indicating certain connectivity groupings.

This vertical pattern shows that the integration value varies greatly for each level of connectivity, which is a common result in urban spatial networks. Even though there are variations, the pattern still shows a good relationship between the two parameters.

5. CONCLUSION

Based on the process of finding the findings above which are the results of measurements from Canggu Village mapping, the research team concluded that:

a. Local connectivity in the network is quite low to moderate. With an average connectivity of 2.46, each segment does not have many direct intersections with other segments, indicating that the road pattern may be rather simple or limited in terms of branching.
b. Local integration within a radius of 3 deviations is also relatively low. With a mean of 1.04, the network may be less locally integrated, meaning movement within a small radius requires more effort (more turns or indirect paths).
c. However, even though connectivity and local integration are low, the intelligibility value is "very good" ($R^2 = 0.87722$) indicating that the structure of this space is quite easy for users to understand. Even though there are some areas that are less locally connected, people moving within the network can still navigate space quite well, because a little local connectivity is still able to predict accessibility within the wider network.
d. Findings from the analysis of points a-c show that the massive development of tourism development in the Canggu Village area has resulted in many branch (minor) roads on the main (major) road, but the large number of branches actually results in an optimal regional spatial structure in terms of ease of understanding for users. to be accessed with good navigation, this is a phenomenon that can be studied further because development is not planned holistically but is able to produce good spatial/spatial connectivity structures, what is the process behind it all? What factors influence it?

Suggested development recommendation:

a. Improving Connectivity in Local Areas: a) Because the average connectivity is only 2.46, increasing the number of intersections or direct routes can help improve local accessibility, especially for tourism areas that must be easily accessible to tourists.; b) The addition of pedestrian paths and dedicated bicycle lanes can improve the tourist experience in moving between destinations, creating a more efficient road network.
b. Increasing Integration Between Tourism Zones: a) With a relatively low integration [HH] 3 value of 1.04, improvement is needed in connecting tourism areas more directly with other activity centers, such as shopping, lodging and recreation areas; b) Designing public transportation routes that are more connected between tourism areas and the city center will increase global integration, so that accessibility for tourists is more efficient and faster.

c. Optimizing Navigation with High Intelligibility: a) With an excellent intelligibility value ($R^{\neg\leq} = 0.87722$), navigation in this area is quite intuitive. However, to support tourism development, it should be noted that clear signage and information in new areas is very important; b) Creating a layout that is easier for visitors to understand - for example by designing simple and integrated routes - will support the tourist experience.
d. Tourism Supporting Infrastructure Development: a) Construction of facilities such as rest areas, cafes and tourist information centers located at points with high connectivity and well integrated can be a supporting element; b) Integrating tourist focal points (landmarks) in spatial planning using the results of integration analysis will make it easier for tourists to recognize and reach main destinations

Involvement of Technology and Smart Tourism: Utilize the results of space syntax analysis to implement smart tourism technology. Information about connectivity and spatial integration can be used in digital navigation applications, so tourists can get the best route guidance in real-time.

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