

Spatial configuration based on relationship between buildings and road network in Oebobo District, Kupang City, East Nusa Tenggara Province, Indonesia

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received December 05, 2023 Received in revised form Jan. 20, 2024 Accepted February 08, 2024 Available online April 01, 2024</p> <p><i>Keywords:</i> Kupang Space configuration Space syntax Qgis</p> <p>*Corresponding author: Amandus Jong Tallo Department of Environmental Engineering, Faculty of Engineering and Computer Science, Bakrie University, Indonesia Email: amandustallo@gmail.com ORCID: https://orcid.org/0000-0002-4037-298X</p>	<p><i>Oebobo District has the highest density level among all sub-districts in Kupang City. The impact of population growth and circulation is that the mobility of people and goods often occurs quickly, thus hampering efficient observation. This research highlights the need for accurate recognition to develop recommended effective and optimal space management and utilization. The focus of this research is population movement patterns by considering spatial structure. Quantitative descriptive research method used over the space syntax approach on QGIS and DepthMapX softwares. Quantification is carried out on the connectivity value to measure the level of connection in the road network and the integration value to reflect the integration between spaces. With the highest connectivity and integration scores, Oebobo District has the potential to become the city center or main activity center in Kupang City.</i></p>

Introduction

Kupang is the center of growth in the province of East Nusa Tenggara. The National Statistics Agency in 2023 states that Kupang has the highest population growth rate in East Nusa Tenggara Province in 2022, which is 2.92%, with a population of 465,640 people. Rapid population growth and economic progress have become key characteristics of cities. In line with these developments, issues related to settlement and population density in Kupang are becoming more complex and profound. As such, mapping the distribution of residential areas and analyzing density are highly relevant and essential topics in

studying the city's development (Tallos et al. 2018).

Land in urban development is generally used for housing to facilitate population growth. Kupang City consists of 6 sub-districts, each with varying levels of population density. Data retrieved from the Central Bureau of Statistics show that the Oebobo sub-district has the highest density in Kupang. Over the past few years, the Oebobo sub-district has experienced significant population growth and changes in population layout patterns, as well as changes in settlement layout patterns, business growth, and changes in land use (Carvalho, Daton, and Mberu 2023). The growing population has the consequence of



increasing the problems that will be faced in the effort to improve the community's quality of life (Tallo et al. 2018; Angin and Sunimbar 2021).

One of the problems resulting directly from population growth and distribution is that mass movement often occurs quickly, hindering efficient observation (Ali and Abidin 2019). Mass movement in Kupang City is associated with activities that utilize open space for various purposes, such as work, education, sports, entertainment, and other activities. In addition, dense neighborhoods can also be associated with higher urban pressures, such as noise pollution impacts, acts of vandalism, higher crime rates, or unsatisfactory housing quality (Beenackers et al. 2018). Temporary and unstable changes in Kupang's urban planning result in irregular human movement and dense interactions, creating an atmosphere of noise and crowding. This can be addressed by planning for improved infrastructure facilities in Kupang, including developing a road network.

Road network development in urban areas is needed to improve living standards and facilitate the survival of people in the area (Koning, Tan, and van Nes 2020). Along with the increasing population growth, network infrastructure development is needed to support economic growth, especially in strategic areas that significantly affect community movement (Insani Lubis and Perwira Mulia 2021).

When various movement characteristics are combined, proper recognition is needed to determine efficient recommendations for organizing and using space more effectively and optimally. Observing and recognizing space-related issues where masses constantly move and create density results in complicated variables. Order can be maintained in complex situations by applying spatial logic and mapping movement patterns, which can serve as guidelines and measures for understanding the mass movement (Romdhoni 2018).

This research centers on analyzing population movement patterns to examine spatial configuration by considering its spatial structure (Noor Fajrina Farah Istiani 2022) with spatial patterns through spatial space syntax analysis. The spatial analysis investigates the influence of space utilization on socioeconomic activities and maps morphological changes due to large-scale urban development (Octifanny and Norvyani 2021).

This study aims to determine which areas of Kupang are suitable as activity centers and determine the availability of space in areas that can become town centers. There are four space syntax analysis types: axial analysis, segment map analysis, visibility graph analysis, and agent-based modeling. In this case, this study uses axial analysis followed by visibility graph analysis.

A spatial configuration approach suitable for this research has been successfully developed using the space syntax method (Elgamal, Sheta, and Foda 2020; Putra 2021). Space syntax is a set of analytical techniques used to describe, measure, and model spatial configurations in urban spaces or buildings, relationships between urban spaces, and how residents use them with the help of numbers and mathematical concepts for urban planning and architectural purposes (Atakara and Allahmoradi 2021; Garnica-Monroy and Alvanides 2019; Pafka, Dovey, and Aschwanden 2020), which are precise in developing sustainable urban features (Yamu, van Nes, and Garau 2021). In addition, space syntax is used to evaluate how residents interact with the spatial layout through visual analysis and to understand the spatial relationship between one street and another (Garnica-Monroy and Alvanides 2019; Khoshnaw 2023), as well as to help understand the direction of urban growth and development (Suchoń and Olesiak 2021), thus illustrating the strong and weak relationships in urban areas (Ribeiro et al. 2021). The space syntax approach focuses on creating a space cognition model based on the topological structure to measure spatial configuration by ignoring form from architectural analysis (Liu, Wang, and Wang 2019; Putra 2021). Regardless of other factors, space syntax patterns in cities are primarily based on the topology of the road network (Şahin Körmeçli 2023).

This research uses two software, namely QGIS and DepthMapX. Geographic information systems (GIS) software collects, integrates, stores, edits, analyses, shares, and displays spatial and geographic information (Atakara and Allahmoradi 2021). In GIS, features are fundamental representations of geographic phenomena, are real-world geographic entities and their digital representations, and share common attributes, relations, and functions (Germanaite et al. 2021). GIS provides technical and theoretical support for integrating massive and multi-source urban data to produce data visualization and comparative analysis as the

basis for urban space studies (Xing and Guo 2022). Quantum GIS (QGIS) is a cross-platform free and open-based GIS application that provides data display, editing, and analysis. QGIS has similar functionality to other GIS software, allowing users to create maps with multiple layers using map projections. Maps can be used in different formats based on their needs (Insani Lubis and Perwira Mulia 2021).

Combining space syntax analysis in one model using GIS allows quantitative tools to contribute to significant advances in spatial analysis of urban morphology (Şahin Körmeçli 2023). Several terms are used in the metric system to determine the relationship between graphs and space syntax results. Theories commonly used in metric calculations include connectivity and integrity. Connectivity is a method to see the degree of relationship between spaces shown from the crossover between spaces. A space that has good space connectivity has the most intersection of spaces with other spaces, so it has a more primary degree of space hierarchy (Romdhoni 2018). At the same time, integrity or integration value is obtained from the number of turning points to reach space and how long the road is. This is used to predict the potential of meetings in an area. Both support the space syntax theory, which states that high building density and land use depend on good connectivity, an integrated road network, and the distance between private property and public space (van Nes and Yamu 2020).

Methods

The research method used is a descriptive quantitative method using the QGIS application to produce calculations of spatial connectivity and integration between observer spaces in Kupang City. Quantitative research is an objective and systematic process for collecting and analyzing numerical information. Quantitative research is divided into experimental and descriptive (non-experimental), which helps researchers solve problems with numerical data to evaluate or describe something. Descriptive quantitative research provides detailed insights into a context with a logical and systematic approach (Yoshimura et al. 2021).

The first step is to import highway, building, and road data in Kupang City into the QGIS

application. Geospatial data in the QGIS application is used to display these elements on a digital map. The next step is to perform space syntax analysis. Space syntax analysis focuses on two main aspects, namely connectivity and integration. To measure connectivity, a standard method calculates the betweenness value, which indicates the extent to which roads in the area are on major crossing routes. Meanwhile, closeness values are calculated to measure integration, describing turning points and how quickly a location can be accessed from other locations in the network.

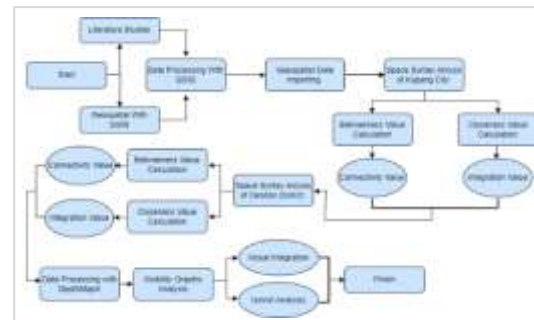


Figure 1. Research flow chart

The first space syntax analysis was conducted at the Kupang City scale to determine the spatial configuration, resulting in one sub-district that could serve as an activity center. The selected sub-district is the area with the highest connectivity and integration scores. Then, a space syntax analysis was conducted at the sub-district scale to see which areas were suitable as activity centers.

QGIS produces differences in the depth of analysis by displaying the red-to-blue color spectrum in each aspect. The red color identifies areas with the most movement and high integration with other spaces and roads. In contrast, blue colors identify areas with the slightest movement and minor integration with other spaces and roads.

In the third stage, in the area with the highest connectivity and integration values, namely the Oebobo Sub-district, a Visibility Graphic Analysis (VGA) was conducted and simulated using the DepthMapX tool. This analysis relates to visuals depicting the space between buildings. Visibility Graph Analysis (VGA) is divided into three methods: visual integration, step depth, and iIsovist analysis. Visual integration describes the space created between buildings and vegetation.



Figure 4. Spatial configuration on connectivity aspects based on building facilities

Roads and buildings in red show the highest connectivity value, followed by orange, yellow, and blue roads. The higher the connectivity value, the better the roads and buildings are for activity, trade, and office centers. They are connected to many other roads and spaces that strengthen the natural movement of economic processes (Yamu, van Nes, and Garau 2021). Meanwhile, blue-colored roads and buildings are suitable for residential areas due to their limited connectivity.

Integration value shows the amount of distance between one space and another. Integration measures the depth of access of an element to all other elements in the overall network (Octifanny and Norvyani 2021). It indicates the potential of a space to become a destination and is related to social gathering, attractiveness, and level of retail activity (Hillier 2008). Spaces with a short distance between spaces will produce a more integrated space compared to spaces with a long distance from other spaces. The axis of the most integrated is automatically shown in red, followed by orange, yellow, green, and blue around it.

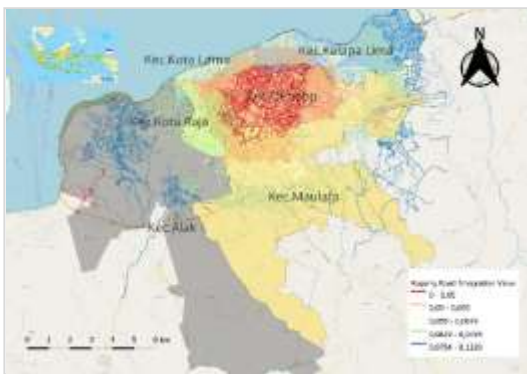


Figure 5. Map of spatial configuration result on integration aspect based on road network

In contrast to connectivity, the greater the calculation value, the greater the connectivity value, and the more red-colored the visual area of streets and buildings. The value of integration is the opposite, where the smaller the number produced, the greater the value of integration and the redder the visual area.

The road network in Oebobo Sub-district has a high integration value marked in red with an integration value of 0-0.05, followed by the surrounding orange color with an integration value of 0.05-0.055, yellow with an integration value of 0.055-0.0619, green with an integration value of 0.0619-0.0754, and finally blue with an integration value of 0.0754-0.1359.

Meanwhile, building facilities in Oebobo Sub-district have an integration value of 0-0.0499, which is marked in red, followed by orange with an integration value of 0.0499-0.0535, yellow with an integration value of 0.0535-0.058, green with an integration value of 0.058-0.0689, and finally blue with an integration value of 0.0689.

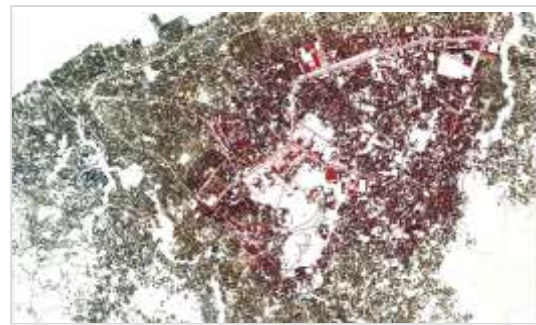


Figure 6. Map of spatial configuration result on integration aspect based on Road Network

Based on the spatial configuration of the road network and buildings in the aspect of integration in Kupang City, the city center of Kupang is integrated into Oebobo Sub-district. This indicates that the Oebobo sub-district receives the most movement and is the most integrated with other spaces or roads, making Oebobo sub-district suitable as the main activity center in Kupang City, such as a city, shopping, or office centers. It is theorized that high integration values are indicated by commercial streets (Miranda and van Nes 2020).



Figure 7. Map of spatial configuration result on integration aspect based on road network

The results of the spatial configuration in the Oebobo Sub-district in the aspects of connectivity and integration based on the road network show that the Oebufu Village area has the highest connectivity and integration values. Oebufu Village has a road network connectivity value of 26981-212066 and a road network integration value of 52-2824. The map of the results of spatial configuration in the aspect of connectivity based on the road network can be seen in figure 7. Meanwhile, the map of the results of spatial configuration in the aspect of integration based on the road network of Oebufu Vilalge can be seen in figure 8.

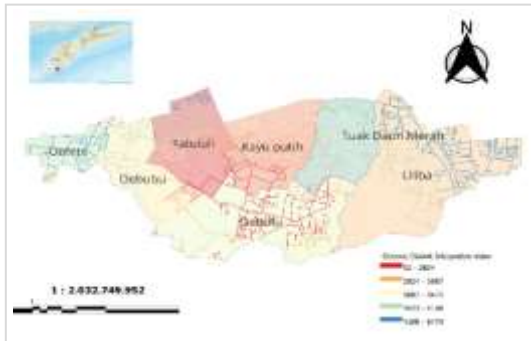


Figure 8. Spatial configuration on integration aspect based on road network of Oebobo sub-district

Based on spatial configuration results in connectivity and integration in the Oebobo Sub-district, Visibility Graphic Analysis (VGA) was conducted in the Oebufu Village area. This research location was selected based on the high value of connectivity and integration in the area. Visibility Graphic Analysis (VGA) includes two methods: visibility integration and iIsovist analysis. The location of the Visibility Graphic

Analysis (VGA) simulation can be seen in figure 9.

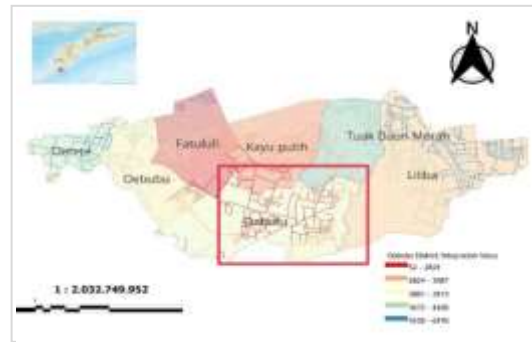


Figure 9. Visibility Graphic Analysis (VGA) locations

The results of Visibility Graphic Analysis (VGA) in Oebufu Village, located in Oebobo Sub-district, which is simulated using the DepthMapX tool, show that empty spaces with high visibility integration values were found in the middle of the residential density of the area. Areas with high visibility integration are marked in red, followed by lower visibility integration values in orange, and then yellow to blue. The visibility integration map of Oebufu Village can be seen in figure 10.

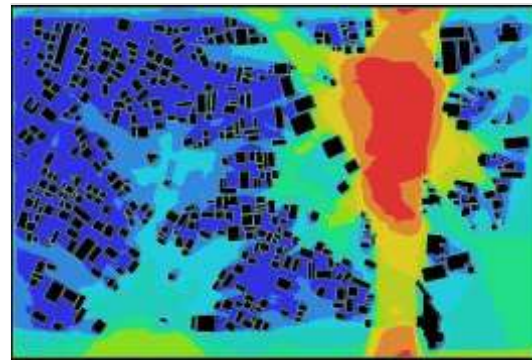


Figure 10. Visibility integration of Oebufu Village

The black boxes in Figure 10 are visualizations of the buildings in Oebufu Village. The red-colored area shows vacant land with a wide range of vision because buildings do not obstruct it. Meanwhile, the dark blue color shows an area with a limited range of vision due to the density of the distance between buildings. This area could be developed into an activity center in the Oebobo Sub-district due to its high visibility integration value. Moreover, if we stand in the area, it will produce a relatively wide range of eyes; this can be simulated with Iisovist analysis

using the DepthMapX tool. The map of Isovists analysis spatial configuration results can be seen in figure 11.



Figure 11. Isovists analysis of Oebobo Village

The grey area results from simulated Isovist analysis within a radius of 360 degrees. It indicates the size of the area that will be captured within the range of our eyes in 360 degrees if someone stands at the red dot, as shown in figure 10.

Conclusions

The study results show that the Oebobo Sub-district, especially in Oebufu Village, is a potential area to be developed as the center of Kupang City. This is because the Oebobo sub-district has the highest connectivity value of 43275-7492895 based on the road network and 468008-7492895 based on building facilities. In addition, Oebobo sub-district has the highest integration value of 0-0.05 based on the road network and 0-0.0499 based on building facilities.

With high connectivity and integration values, the area in the Oebobo Sub-district, especially in Oebufu Village, can be developed as a commercial center such as a city, shopping, or office centers. However, further research needs to be done to analyze the level of economic development in the area from the planned activities.

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Author(s) contribution

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Aqilla Farida Azzahra Arifin investigations, data analysis, visualization, and articles drafting.

Muhammad Faza Izdhihar contribute to methodology, supervision, and validation.

Amandus Jong Tallo contributed to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

