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Growth Center Identification and Accessibility-Based Spatial Interaction in Bondowoso Regency

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Abstract

Bondowoso Regency, as a developing rural and semi-urban area, faces dynamic development challenges, particularly inter-district development disparities and uneven concentrations of economic activity. This inequality reflects a disparity between districts in terms of facilities, accessibility, and the distribution of economic activity centers. The determination of growth centers is a crucial strategy for identifying areas with the potential to be drivers of development. This study aimed to determine the growth center and the accessibility-based spatial interaction in Bondowoso Regency, East Java, Indonesia. The methods used for this study were scalogram, gravity, and overlay analysis. The results showed that Bondowoso District has 561 facility units with a regional development index value of 69.86 (Hierarchy I). This indicates its role as a growth center that can influence the strength of spatial interactions between districts in Bondowoso Regency. The highest spatial interaction value was found in Tenggarang District at 39,708, while the lowest was in Sukosari District at 3,980. The optimization of these central places is expected to create a polarization effect and increase the attractiveness of the surrounding areas. This can be a consideration for the Bondowoso Regency government in determining the direction of development to reduce inter-regional inequality

Keywords: *Accessibility Index, Bondowoso Regency, Growth Center.*

1. Introduction

Bondowoso Regency, one of the regencies in East Java, Indonesia faced various development challenges. Where the conditions were unfavorable due to its limited resources, no marine wealth, and exclusion from national routes. As a result, the economic growth of Bondowoso Regency was consistently lower compared to neighboring regencies, such as Banyuwangi, Jember, and Situbondo, which border it directly (the Central Bureau of Statistics of Bondowoso Regency, 2024). The slow economic growth that happened in Bondowoso Regency highlighted the need for the establishment of growth centers in districts as an effort to encourage regional development and achieve regional balance. Economic growth in districts designated as growth centers was expected to influence the surrounding districts through a process known as the polarization effect, subsequently leading to a trickle-down effect (Vidriza, 2024). Historically, the trickle-down effect had been shown to develop by enhancing the attractiveness of the surrounding areas (Wontiana & Sunarto, 2018).

Growth centers functioned as regions that drove the economy due to their wide range of services, potential for growth in various economic sectors, and its growth was faster on a local and regional scale (Rossi, 2020). These centers also had the potential to emerge as superior areas, both in terms of

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geographical location and natural resources, enabling them to stimulate the economic growth of surrounding areas (Safira et al., 2023). Research conducted by Dhali et al., (2019) indicated that growth centers were marked by increased physical activity, as evidenced by changes in land cover. The higher the level of physical activity, the greater the attraction for interaction resulting from movements between one and another (Hariayanto, 2017). This demonstrated a clear relationship between growth centers and regional interactions (Iyer & Thomas, 2020).

The close relationship between growth centers and regional interactions was reflected in a distributed network through the scale of connectivity and the size of the service hierarchy (Mansury & Shin, 2015). A high connectivity figure indicated strong interactions between growth centers (districts) and the surrounding districts (Vidriza, 2024). The selection of the Bondowoso Regency was conducted to encourage regional growth through adequate planning and management efforts, given that Bondowoso Regency possessed significant potential, particularly in the agricultural, plantation, and tourism sectors. However, this potential had not been optimally utilized (the regional space order plan of Bondowoso Regency, 2024-2044). To maximize the balance of resources in each district, growth centers were established to facilitate interactions between district areas. This effort was supported by the fifth vision of the regional space order plan of Bondowoso Regency for 2024-2044, which aimed to develop strategic areas as drivers of the regional economy in each district. Through this vision, the development of the Bondowoso Regency area focused on leveraging the potential of each district to drive economic growth.

A recent literature review indicated that Bondowoso Regency occupied the fourth position in the hierarchy of East Java Province based on the scalogram index (Taufiqqurrachman, 2024). In the Besuki residency area, according to the scalogram index, Bondowoso Regency ranked third after Jember and Banyuwangi Regencies (Putra et al., 2017). The determination of the growth center hierarchy was also carried out in the Ijen Ring area, where the regional hierarchy indicated that Bondowoso and Curahdai Districts in Bondowoso Regency were positioned as second-tier growth centers (Ristanto, 2024). Although studies on growth centers and regional interactions had been conducted in Indonesia, particularly in East Java, available research remained limited and did not focus on Bondowoso Regency.

As a developing region, Bondowoso Regency is experiencing the formation of economic agglomerations, leading to the emergence of growth centers. According to Myrdal (1957), this phenomenon can generate a "spread effect" into less developed surrounding areas through the diffusion of innovation and the expansion of export markets for local products. The strategic establishment of distributed growth centers is a recognized strategy for reducing inter-regional development disparities (Sjafrizal, 2012). This approach is effective because the growth center concept simultaneously embraces both concentration and decentralization. Consequently, new growth centers can be stimulated to achieve significant development (Rustiadi et al., 2011). The development of district-level growth centers within Bondowoso Regency is anticipated to stimulate growth in other districts through a "trickle-down" process, thereby mitigating regional inequality. Therefore, the objectives of this study were to: (1) identify the primary growth centers within the regency, and (2) quantify the spatial interaction values between the districts. To the best of our knowledge, this is one of the first studies to analyze growth centers and inter-district interactions in this specific region. The findings of this research were crucial for guiding regional development strategies, reducing developmental disparities, and providing an evidence-based foundation for policymaking by the Bondowoso Regency government

2. Data and Method

2.1 Location

The study was conducted in Bondowoso Regency. It is comprised of twenty-three districts. According to Bondowoso Regency's 2024 Regional Regulation No. 3 concerning Bondowoso Regency's 2024-2044 Regional Spatial Planning, the regency's spatial structure plan is a system of settlement centers and infrastructure networks. The precise research location can be seen below in Figure 1.

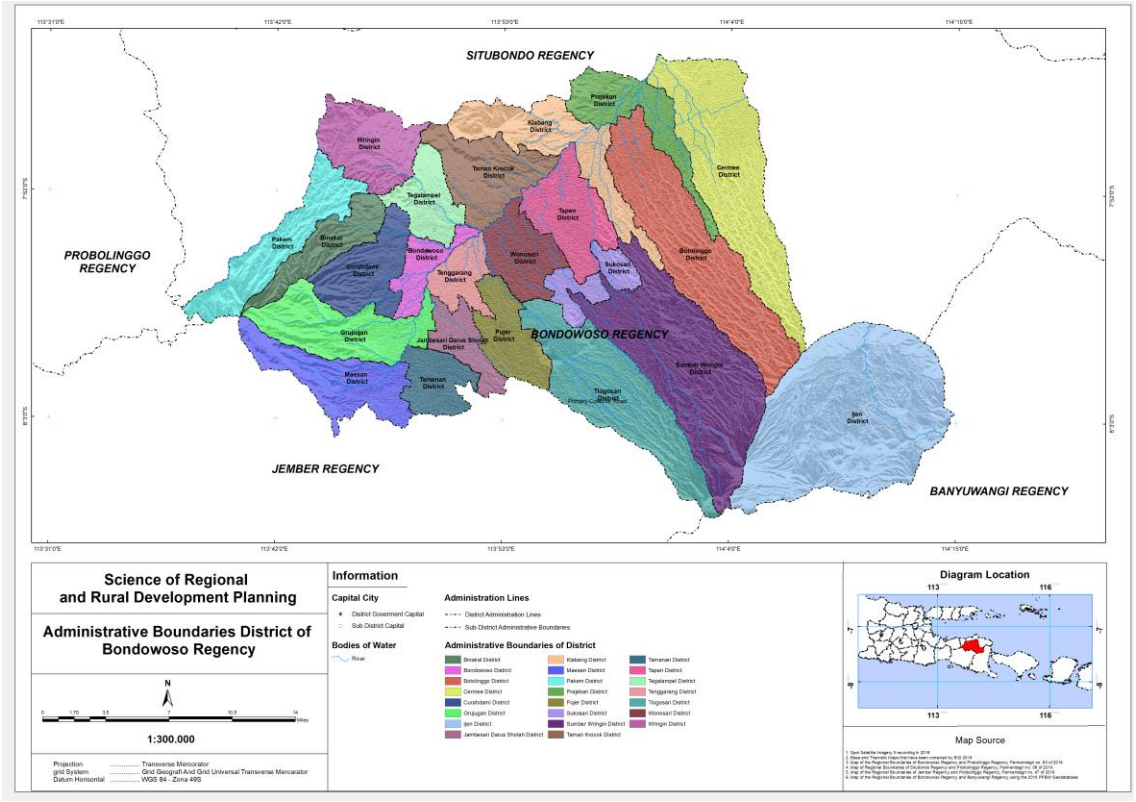

Figure 1. Research Location in Bondowoso Regency
Source: Modified from Bondowoso Regency Spatial Planning Plan, 2024-2044

2.2 Data

This study used secondary data from various agencies such as the Central Bureau of Statistics, the Population and Civil Registration Service, the regional spatial planning of Bondowoso Regency (*RTRW – Rencana Tata Ruang Wilayah*) for 2024-2044, and Google Maps. The data collected included wide region, total population, population density, road length, the distance between districts to the district capital (in kilometers and minutes), and social and economic facilities. Details of the data in this study is presented in Table 1 below.

Table 1. List of data in Bondowoso Regency

No	Data Type	No	Data Type
1	Total Area (Ha)	**15**	Senior high school
2	Total Population	**16**	University
3	Road (Km)	**17**	Hospital
4	Population Density	**18**	Clinic
5	Distance from Sub-district to Regency Capital (km and minutes)	**19**	Health center
6	Traditional Market	**20**	Posyandu
7	Supermarket	**21**	Pharmacy
8	Koperasi	**22**	Office facilities
9	Restaurant	**23**	Musholla
10	Hotel	**24**	Mosque
11	Residential Estate	**25**	Church
12	Kindergarten	**26**	Vihara
13	Elementary school	**27**	Pura
14	Junior high school	**28**	Bus Station

Source: Analysis, 2024

2.3 Data Analysis Techniques

The analysis used in this study was a quantitative approach with data analysis, namely scalogram analysis and gravity index analysis with the following stages:

2.3.1 Scalogram Analysis

Scalogram analysis consisted of three primary methods: the Gutmann scales method, the simple scalogram analysis method, and the modified scalogram method. These methods exhibited significant differences. The Gutmann scales model was qualitative, the simple model was quantitative considering the number and types of service facilities, while the modified model not only accounted for the presence of service facilities but also incorporated aspects of service capacity and accessibility, including physical distance and travel time to each facility (Panuju & Rustiadi, 2013). This study employed the modified

scalogram analysis method, as it was regarded as a more comprehensive approach, integrating and simplifying aspects of the scalogram methods.

The data utilized in this study were sourced from the Central Bureau of Statistics of Bondowoso Regency, the Education and Civil Registration Office of Bondowoso Regency, Google Maps, and prior studies. The parameters measured included social and economic facilities, the distance of each facility, and the distance from the district center to the center of Bondowoso Regency. All data were processed under the assumption that the weight assigned to each facility varied. The scalogram analysis procedure is detailed as follows.

1. Determining Inverse Distance with the Formula:
   $B_{ij} = 1/X_{ij}$
   where
   B_{ij} : Inverse data index
   X_{ij} : Data value of district i based on variable j
2. Calculating the Facility Index per1000 Population:
   $A_{ij} = F_{ij}/Pi*1000$
   where
   A_{ij} : facility index for facillity j in district i,
   F_{ij} : Number of facility j in district i
   Pi : Population of district i
3. Calculating the Weighted Index for Key:
   $I_{ij} = A_{ij}$*weight
   where
   I_{ij} : Weighted index for facility jjj in district iii,
   A_{ij} : Facility index for facility jjj in district iii (per 1000 residents)
4. Calculating the value of the district development index with standard values due to differences in the units of each variable using the formula:
   $K_{ij} = I_{ij} – \min(I)j/S_j$
   where
   K_{ij} : Standardized hierarchy index value
   I_{ij} : weighted value of 1st district and j facility
   Min(I)j : minimum index value for facility j,
   S_j : standard deviation value

2.3.2 Gravity Index Analysis

The gravity index analysis, developed by Hansen as cited in Lee (1973), was utilized to predict locations based on the attractiveness of each site. This model was employed in the research to hypothesize that the presence of activity centers, the number of facilities, and the level of accessibility could influence changes in land cover or land use. Generally, the accessibility index was determined by the attractiveness between sub-regions and the ease of reaching each sub-region. The accessibility index was calculated using the formula proposed by Lee (1973).

$$Aij = \sum_{j=i}^{n} \frac{E_i}{d_{ij^b}}$$

where
A_{ij} : accessibility index of region i to region j
E_j : total available land
D_{ij} : distance between region i and region j,
b : rank of D_{ij}

To determine the attractiveness between districts, the development potential of each region had to be compared with the overall attractiveness of all locations

$$D_i = \frac{A_i\, H_i}{\sum_{j=i}^{n} A_i\, H_i}$$

Dimana
A_i : Accessibility index
H_i : Total Area

2.3.3 Overlay Analysis

The analysis process, which combined information from several different data layers using spatial operations, was a Geographic Information System analysis conducted with ArcGIS software (Safira et al., 2023). This method was used to describe the results of both analyses, making it easier for readers to understand them. Visualization in the form of a map provided an accurate depiction of Bondowoso Regency after the scalogram and gravity analysis processes were completed.

3. Result and Discussion

3.1 Scalogram Analysis of Bondowoso Regency Growth Center

In this study, scalogram analysis was employed to describe the characteristics of the development of the Bondowoso Regency area by identifying service centers based on the level of regional hierarchy, namely Hierarchy I, Hierarchy II, and Hierarchy III. The level of regional hierarchy was determined by the value of the District Development Index (DDI); the higher the DDI value, the more developed the district was (Table 2). Regional growth centers in Bondowoso Regency were analyzed using indicators such as the number of infrastructures and accessibility to urban centers, including the distance from the sub-district capital to the district capital. By identifying these growth centers, it became evident which administrative areas functioned as influential growth hubs (Safira et al., 2023).

Based on the results of the weighted scalogram analysis conducted in Bondowoso Regency, which comprises twenty-three districts, it was found that Bondowoso District had the highest DDI value among the districts, with a value of 69.86, placing it in Hierarchy I. This indicated a very high level of regional development. When examined from the perspective of its function, Bondowoso District serves as the urban center and capital of Bondowoso Regency. The next highest DDI values were observed in eight districts consecutively: Ijen District with a DDI value of 39.32; Klabang District with a DDI value of 37.73; Sukosari District with a DDI value of 37.40; Tegalampel District with a DDI value of 37.33; Prajekan District with a DDI value of 36.17; Taman Krocok District with a DDI value of 32.26; Tenggarang District with a DDI value of 30.65; and Binakal District with a DDI value of 30.02, all classified under Hierarchy II. The remaining fourteen districts, namely Maesan, Grujugan, Tamanan, Jambesari Darus Sholeh, Tlogosari, Sumber Wringin, Tapen, Wonosari, Curahdami, Pakem, Wringin, Botolinggo, and Cermee, were categorized as Hierarchy III. For further details related to the results of the weighted scalogram analysis, refer to Table 2 and Figure 2 below.

Table 2. District Hierarchy in Bondowoso Regency

No	District	District development index	Hierarchy
1	Maesan	24,80	Hierarchy 3
2	Grujugan	27,12	Hierarchy 3
3	Tamanan	22,94	Hierarchy 3
4	Jambesari Darus Sholeh	20,84	Hierarchy 3
5	Pujer	27,33	Hierarchy 3
6	Tlogosari	18,18	Hierarchy 3
7	Sukosari	37,40	Hierarchy 2
8	Sumber Wringin	22,38	Hierarchy 3
9	Tapen	28,58	Hierarchy 3
10	Wonosari	23,73	Hierarchy 3
11	Tenggarang	30,65	Hierarchy 2
12	Bondowoso	69,86	Hierarchy 1
13	Curahdami	13,63	Hierarchy 3
14	Binakal	30,02	Hierarchy 2
15	Pakem	20,67	Hierarchy 3
16	Wringin	19,85	Hierarchy 3
17	Tegalampel	37,33	Hierarchy 2
18	Taman Krocok	32,26	Hierarchy 2
19	Klabang	37,73	Hierarchy 2
20	Ijen	39,32	Hierarchy 2
21	Botolinggo	24,83	Hierarchy 3
22	Prajekan	36,17	Hierarchy 2
23	Cermee	23,21	Hierarchy 3
	Minimum	13,63	
	Standard Deviation	11,31	
	Average	29,08	

Source: Analysis, 2024

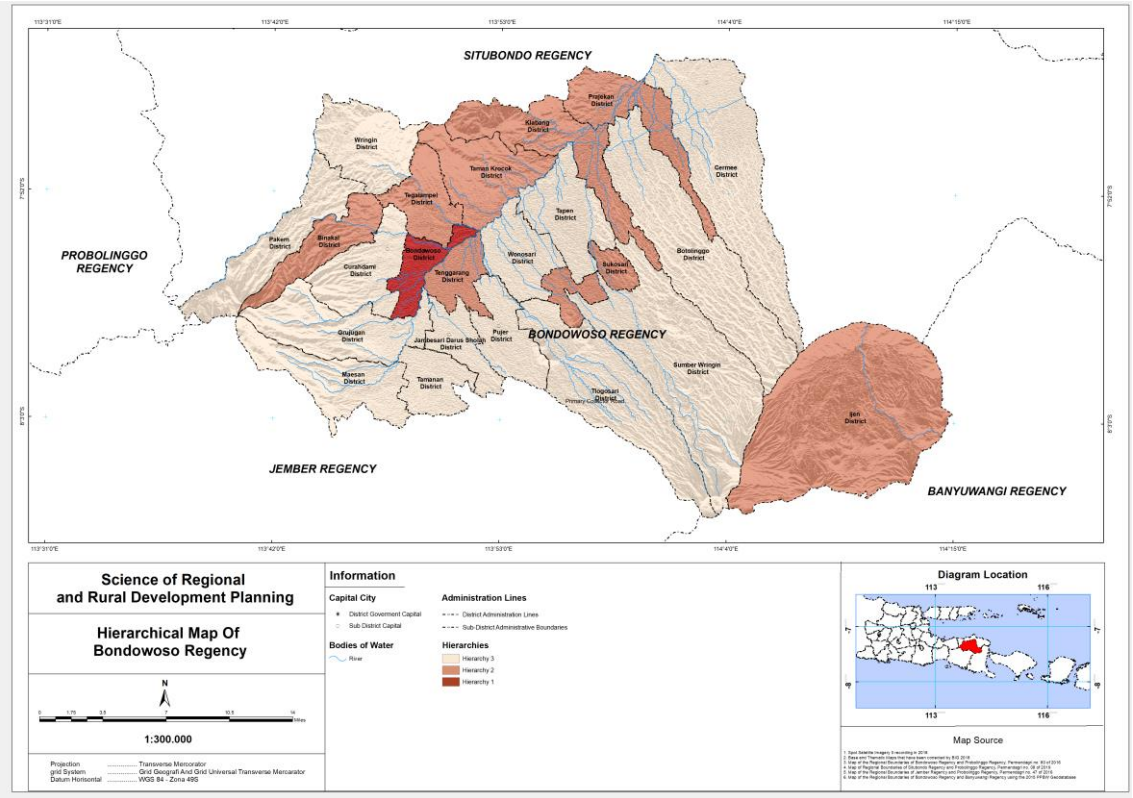

Figure 2. Hierarchical map in Bondowoso Regency
Source: Analysis, 2024

3.2 Accessibility Index Analysis of Bondowoso Regency

The aspect of regional interaction was a crucial consideration in planning regional growth centers (Yusliana et al., 2020). the strength of relationships and development levels across the Bondowoso Regency area by analyzing spatial interactions, or the accessibility index, among districts using the gravity model. In general, the accessibility index reflects both the attractiveness of a sub-region and the ease with which it can be reached. This model measures the attraction between regions based on variables of distance and population in each area under study (He et al., 2017; Liu et al., 2020; Yusliana et al., 2020).

In measuring the accessibility index using the gravity model, the data used were the population of Bondowoso Regency and the population of each district, the number of social and public facilities in each district, settlement centers, and the length of roads in each district. Meanwhile, the distance between each district was measured using Google Maps according to the existing road conditions in kilometers (km). The results of the calculation of the accessibility index of each district in Bondowoso Regency could be seen in Table 3.

The accessibility index of Bondowoso Regency based on the mass of population and distance between regions (Table 3.) showed a variety of relationship strengths. The results of the accessibility index calculation using the Hansen Gravity Model show that the level of inter-district connectivity in Bondowoso Regency varies sharply, and this pattern becomes more apparent when directly compared with the spatial visualization of the accessibility index map. Districts with the highest index values, specifically Tenggarang (0,0887), Sumber Wringin (0,0849), Maesan (0,0839), and Tlogosari (0,0818), occupy strategic positions along the main corridor of the primary collector road network that connects the regency center with surrounding areas. This is evident from their location on the map, situated along the main transportation corridor that supports regional mobility. These areas also demonstrate dense settlement concentrations, indicating a high intensity of population activities and strong physical accessibility. This finding is consistent with the high interaction values in the table, ranging from 29.000 to 39.700, which indicate strong functional linkages between these districts and the main growth center of Bondowoso Regency.

In contrast, districts with low to very low index values, such as Sukosari (0,0089), Jambesari Darus Sholeh (0,0164), Binakal (0,0118), Wringin (0,0418), as well as peripheral areas including Cermee, Ijen, and Botolinggo, exhibit contrasting spatial patterns. On the map, these areas are located far from the primary road network hierarchy, feature more challenging topographic conditions, and have dispersed settlement patterns. The interaction values in the table also show low levels of inter-district interaction (3.980–12.722), which explains the low accessibility index values. This structural disconnectedness is clearly reflected on the map through limited transport connectivity and low proximity to major service centers. These findings suggest that accessibility in Bondowoso Regency remains concentrated in the core areas and decreases gradually toward the periphery, reflecting a spatial structure that continues to

follow a monocentric pattern with a dominant center in urban Bondowoso. For further details on the Bondowoso Regency accessibility index analysis results, refer to Table 3 and Picture 3 below.

Table 3. Accessibility index in Bondowoso Regency

No	District	Population (thousand)	Total Area (sq.km)	Interaction Value	Index Value	Interpretation
1	Maesan	49.312	56,08	37.552,48	0,0839	Very High
2	Grujugan	38.271	74,44	23.789,76	0,0532	Moderate
3	Tamanan	39413	28,15	9.353,28	0,0209	Very Low
4	Jambesari Darus Sholeh	36.848	30,10	7.374,12	0,0164	Very Low
5	Pujer	41.268	39,88	14.192,02	0,0317	Low
6	Tlogosari	47.459	110,91	36.596,88	0,0818	Very High
7	Sukosari	15.668	23,17	3.980,33	0,0089	Very Low
8	Sumber Wringin	35.622	137,94	37.974,00	0,0849	Very High
9	Tapen	34.459	57,04	19.285,86	0,0431	Moderate
10	Wonosari	41.293	42,27	14.646,29	0,0327	Low
11	Tenggarang	44.310	25,79	39.708,25	0,0887	Very High
12	Curahdami	35.146	50,28	31.593,88	0,0706	High
13	Binakal	17.436	39,03	5.287,92	0,0118	Very Low
14	Pakem	23.886	62,08	10.954,67	0,0245	Very Low
15	Wringin	41.183	58,10	18.693,45	0,0418	Moderate
16	Tegalampel	26.789	37,02	22.168,94	0,0495	Low
17	Taman Krocok	49.312	53,00	30.024,46	0,0671	High
18	Klabang	35.622	37,02	29.282,62	0,0654	High
19	Ijen	34.459	53,00	12.722,39	0,0284	Low
20	Botolinggo	41.293	91,20	11.731,97	0,0262	Low
21	Prajekan	44.310	207,20	13.345,51	0,0298	Low
22	Cermee	99.955	129,20	17.295,06	0,0386	Low

Source: Analysis, 2024

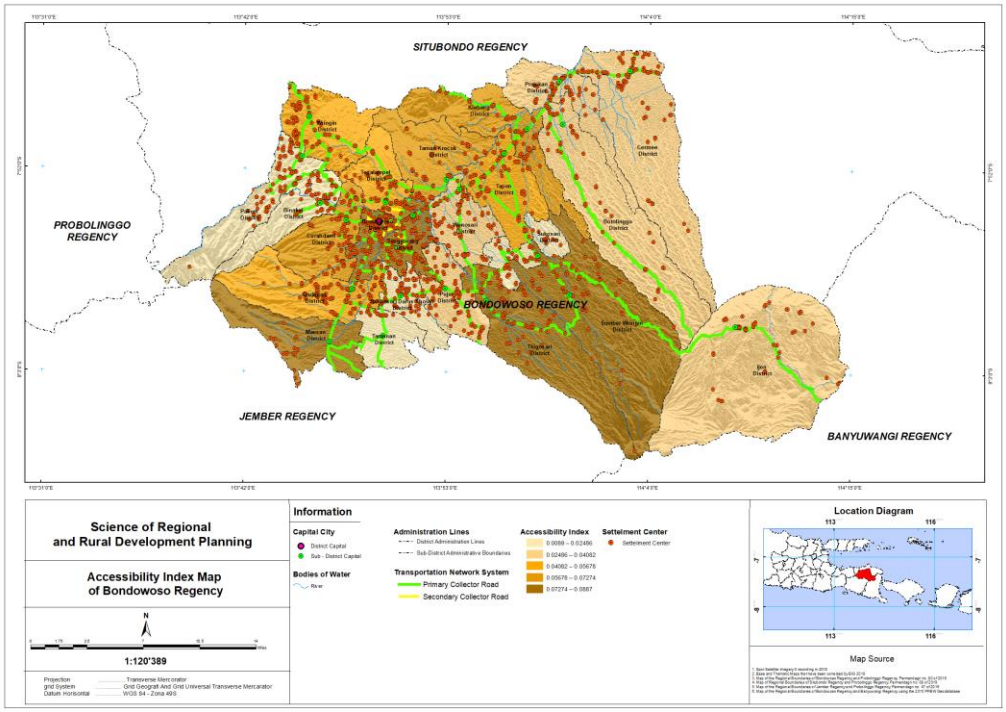

Figure 3. Accessibility index Map in Bondowoso Regency
Source: Analysis, 2024

3.3 Discussion

The acceleration of regional development through structured development strategies and regional hierarchy aimed to ensure that regional development adhered to designated functions and roles, fostering a more equitable development pattern (Rachmawatie, 2024). The findings of this study revealed that Bondowoso District held the highest position in the regional hierarchy (hierarchy I), consistent with the Bondowoso Regency Spatial Plan (2024-2044), which identified the Local Activity Center (*Pusat Kegiatan Lokal - PKL*) within Bondowoso District. It meant that Bondowoso District had comprehensive facilities—including education, administrative offices, economic centers, hospitals, and places of worship—positioning it as a hub for industrial and service activities catering to the district level and as a key transportation node. Additionally, regions with a higher hierarchical rank exhibited enhanced accessibility (Suryana et al., 2021). Better accessibility made it easier for the public to reach a facility from a certain location (Ardeasari, 2021). Consequently, the regional development strategy in Bondowoso Regency with Bondowoso District as its growth center, was expected to exert a positive influence on neighboring districts, generating a polarization effect and resulting in a trickle effect (Brueckner & Lederman, 2018; Taufiqqurrachman, 2024; Vidriza, 2024). Thus far, this trickle effect demonstrated potential for growth by increasing the attractiveness of surrounding areas (Wontiana & Sunarto, 2018).

In hierarchy II, the districts identified as growth centers with a moderate level of development were Sukosari, Tenggarang, Binakal, Tegalampel, Taman Krocok, Klabang, Ijen, and Prajekan districts. Ijen district was the area with the highest DDI (39.32) in hierarchy II. This was supported by adequate infrastructure due to the National Strategic Project (NSP) for the Ijen area (Presidential Regulation No. 80, 2019). Furthermore, there was the determination of the Ijen Geopark area as a geo-tourism area which aimed to preserve natural resources and cultivation, as well as encourage the welfare of the community around the Ijen area (Mastika et al., 2023). Meanwhile, based on the regional space order plan of Bondowoso Regency for 2024-2025, Ijen district was designated as an Environmental Service Center (ESC), which functions to serve inter-village scale activities (Nusantara et al., 2024). Recognizing the substantial potential of Ijen District, the local government prioritized the development of this area so that it could become a service center exerting a polarizing effect in the future.

In hierarchy III, it showed that there were limited facilities in 14 sub-districts, specifically Maesan, Grujugan, Tamanan, Jambesari Darus Sholeh, Pujer, Tlogosari, Sumber Wringin, Tapen, Wonosari, Curahdami, Pakem, Wringin, Botolinggo, and Cermee districts. In terms of composition, Bondowoso Regency was primarily comprised of areas within Hierarchy III. Curahdami district had Bondowoso Regency was dominated by areas with hierarchy III. Curahdami district was the area with the lowest IPK (13.63) in hierarchy III. Geographically, this district was directly adjacent to the growth center, Bondowoso district, yet the proximity exerted a negative influence on Curahdami's development. This phenomenon, known as the spillover effect, describes the impact resulting from the interdependence between regions (Laksono et al., 2018; Qibti & Hendarto, 2020; Sari & Wahed, 2023).

The determination of priority development areas was conducted by identifying regions lagging in accessibility to growth centers. The growth center of Bondowoso Regency, based on scalogram analysis, was located in Bondowoso District. In this context, a large accessibility index value indicated a close relationship between the growth center and its surrounding areas (Umage et al., 2024). The established accessibility pattern within Bondowoso Regency exhibits a centrally focused spatial connectivity structure (core–periphery) with Bondowoso district functioning as the primary growth core. The high accessibility index values in the core districts, which gradually decrease toward the peripheral areas, strongly confirm the fundamental accessibility concept proposed by Hansen (1959), stating that the ease with which an area can reach centers of activity determines the intensity of its socio-economic interactions. In this context, districts with high accessibility indices possess significantly greater opportunities for interaction, population mobility, and service connectivity compared to areas with lower indices.

This hierarchical pattern aligns with Perroux's (1955) growth pole theory, which explains that economic activities tend to concentrate at specific growth points, thereby generating regions with greater attractiveness. Bondowoso and Tenggarang districts function as these growth poles, producing spread effects toward their surrounding districts. Conversely, districts with low accessibility indices demonstrate the phenomenon of backwash effects, characterized by the attraction of resources to the central region, which consequently weakens local growth capacity. This phenomenon is commonly observed in areas facing complex topographical conditions and limited infrastructure networks.

Spatially, the gradient of accessibility values, which systematically decreases from the core towards the southern and eastern parts of Bondowoso Regency, demonstrates the application of the distance decay principle (Tobler, 1970). The analysis results indicate that travel distance, road network quality, and physical barriers are significant factors that diminish the potential for inter-district interaction. Studies in various countries also indicate that limited accessibility is one of the main drivers of interregional development disparities, particularly in rural areas that rely heavily on road connectivity and public services (Liu et al., 2019; Wang & Chen, 2015).

From a regional economic perspective, improved accessibility is proven to directly impact the reduction of logistics costs, the enhancement of labor mobility, and the expansion of local markets (Lakshmanan, 2011). This finding resonates with the work of Geurs and van Wee (2004), who assert that accessibility is a key indicator for evaluating the effectiveness of land-use and transportation interventions. Consequently, low-index areas in Bondowoso Regency are at risk of experiencing functional isolation

unless they receive adequate planning intervention through improvements in road networks, public transport, and the reinforcement of regional service centers.

4. Conclusion

Based on the scalogram analysis calculations, which were conducted using the number of facilities and distances between districts, Bondowoso district emerged as the economic growth center of Bondowoso Regency. This status was closely tied to Bondowoso district's role as the regency capital and its designation as a Local Activity Center (PKL-Pusat Kegiatan Lokal), establishing it as the hub for government, trade, and services, as well as a model for growth and development for other districts. Then, districts with a strong accessibility index to this economic center included Tenggarang, Maesan, Tlogosari, Sumber Wringin, and Curahdami. The remaining 17 districts were categorized under medium to weak accessibility indices. These findings provided a comprehensive overview of spatial interaction strength and regional service capacity. This insight is crucial for formulating targeted development intervention strategies, particularly in prioritizing low-potential areas to ensure balanced regional development.

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