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Spatial Accessibility and Village Development in Pidie Jaya Regency, Aceh, Indonesia

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ABSTRACT

Village development is shaped by social, economic, and environmental conditions, including spatial access to essential services. This study examines the relationship between accessibility to educational, healthcare, and economic facilities and village development, measured using the Village Development Index, in Pidie Jaya Regency, Aceh, Indonesia. A quantitative approach combining spatial network analysis and multiple linear regression was applied to 222 villages. Accessibility was measured using ArcGIS Closest Facility Network Analysis to calculate road-network distances from village settlement centers to the nearest schools, hospitals, community health centers, auxiliary health posts, and markets. Regression analysis used HC3 heteroskedasticity-robust standard errors. The accessibility variables collectively explained 22.5% of the variation in IDM scores ($R^2 = 0.225$). Distances to senior high schools, hospitals, and auxiliary health posts showed statistically significant negative associations with IDM scores, while distances to elementary schools, junior high schools, community health centers, and markets were not significant. These findings support spatially targeted infrastructure and service planning for underserved villages. The observed relationships indicate association rather than causality.

Keywords: Educational Facilities; Healthcare Facilities; Road Network Analysis; Spatial Accessibility; Village Development Index

ABSTRAK

Pembangunan desa dipengaruhi oleh kondisi sosial, ekonomi, dan lingkungan, termasuk akses spasial terhadap pelayanan dasar. Penelitian ini menganalisis hubungan antara aksesibilitas fasilitas pendidikan, kesehatan, dan ekonomi dengan tingkat pembangunan desa yang diukur menggunakan Indeks Desa Membangun (IDM) di Kabupaten Pidie Jaya, Aceh, Indonesia. Pendekatan kuantitatif yang mengintegrasikan analisis jaringan spasial dan regresi linier berganda diterapkan pada 222 desa. Aksesibilitas diukur menggunakan Closest Facility Network Analysis pada ArcGIS untuk menghitung jarak melalui jaringan jalan dari pusat permukiman desa menuju sekolah, rumah sakit, Puskesmas, Pustu, dan pasar terdekat. Analisis regresi menggunakan galat baku robust HC3. Variabel aksesibilitas secara bersama-sama menjelaskan 22,5% variasi skor IDM ($R^2 = 0{,}225$). Jarak menuju SMA, rumah sakit, dan Pustu menunjukkan hubungan negatif yang signifikan secara statistik dengan skor IDM, sedangkan jarak menuju SD, SMP, Puskesmas, dan pasar tidak signifikan. Temuan ini mendukung perencanaan infrastruktur dan pelayanan berbasis prioritas spasial bagi desa yang kurang terlayani. Hubungan yang ditemukan menunjukkan asosiasi, bukan hubungan sebab-akibat.

Kata Kunci: Aksesibilitas Spasial; Analisis Jaringan Jalan; Fasilitas Kesehatan; Fasilitas Pendidikan; Indeks Desa Membangun

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INTRODUCTION

Village development is an important effort to improving community welfare and reducing poverty through the provision of essential infrastructure and public services (Gaspersz, 2023). In Indonesia, village development is assessed using the Village Development Index (*Indeks Desa Membangun*, IDM), a composite indicator covering social, economic, and environmental resilience, as established under Regulation of the Minister of Villages, Development of Disadvantaged Regions, and Transmigration No. 2 of 2016. Unlike conventional poverty indicators based mainly on household income or consumption, IDM provides a broader assessment of village development and self-reliance (Hilmawan et al., 2023).

Although village development and poverty alleviation are closely related policy goals, they are conceptually distinct. Examining access to educational, health, and economic services is therefore relevant to understanding differences in village development, particularly where geographical conditions and infrastructure distribution may constrain access to essential services.

Higher levels of village development are generally associated with better access to public services and economic opportunities. Educational facilities can support human capital development, healthcare services contribute to population well-being, and economic infrastructure can facilitate productive activity. Conversely, inadequate infrastructure and limited access to essential services may restrict opportunities for socioeconomic advancement and reinforce persistent disadvantage. Agustina and Yahya (2022) examined the relationship between village development and poverty in Indonesia, while Brady (2023) emphasized the importance of structural and institutional conditions in explaining persistent poverty. Together, these perspectives suggest that improved accessibility to essential facilities may support village development and contribute to broader poverty-reduction goals.

Previous studies have identified a range of infrastructural and institutional characteristics associated with village development. Ramadhani and Adi Saputra (2024), examining 5,312 villages in West Java, found that the availability of social infrastructure and the effectiveness of village economic institutions were important factors in rural development. Similarly, Nadia and Mahi (2023) investigated changes in IDM scores in relation to village funding and the educational attainment of village heads. Their findings indicated that village fund management was more effective in supporting village development when village heads had educational attainment above the senior high school level. Amelia et al. (2026) further

examined infrastructure-related determinants of IDM status on Madura Island using ordinal logistic regression and machine-learning approaches. Their results identified significant associations involving healthcare facilities and equitable access to schools in the ordinal regression model. Together, the studies show the relevance of infrastructure and institutional conditions to village development, although their explanatory variables and analytical approaches differ.

Spatial accessibility has also been examined in relation to the distribution and utilization of essential services. Ayyumi et al. (2022) analyzed the spatial distribution and service coverage of elementary, junior high, and senior high schools in Tarogong Kidul, Indonesia, using nearest-neighbor and buffer analyses. Their findings showed variations in the distribution and service coverage of educational facilities. In the healthcare sector, Wenang et al. (2021) investigated the availability and utilization of primary healthcare services among remote, rural, and disadvantaged populations in Indonesia and documented geographical disparities in healthcare resources and service use. From an economic perspective, Li and Cao (2024) examined geographical disadvantages associated with distance to markets in China, highlighting the economic burdens of market remoteness. These studies demonstrate the relevance of geographical accessibility to educational, healthcare, and economic conditions. However, they do not directly establish statistical relationships between road-network accessibility and composite measures of village development.

Despite the contributions they offer, existing studies have examined infrastructure and village development using different measurement approaches and geographical points of view. Research on village development largely focused on infrastructure availability, institutional conditions, fiscal resources, and service-related characteristics, whereas spatial-accessibility studies have emphasized facility distribution, geographical coverage, and sector-specific socioeconomic outcomes.

A particularly relevant contribution is provided by Gaspersz (2023), who examined the relationship between essential-service availability and categorized village development status in Maluku and North Maluku using logistic regression. Nevertheless, the relationship between network-based distances to multiple essential facilities and continuous IDM scores at the village level remains insufficiently addressed in the literature reviewed here.

This distinction is important because the presence of a facility within an administrative area does not necessarily indicate that it is physically accessible through the existing transportation network. Integrating road-network accessibility measurements with village-level IDM scores therefore offers a complementary approach to examining geographical disparities in rural development.

Pidie Jaya Regency, located in Aceh Province, Indonesia, provides a relevant geographical context for investigating these relationships. The regency comprises eight subdistricts and 222 villages with varying geographical conditions, settlement patterns, and levels of infrastructure accessibility. On 7 December 2016, Pidie Jaya experienced a magnitude 6.5 earthquake that caused extensive damage to buildings and infrastructure, as documented by Idris et al. (2022). Although this disaster provides important historical context for regional development, current accessibility disparities cannot be attributed directly to the earthquake without additional empirical evidence.

Furthermore, the spatial distribution of village development categories based on 2023 IDM data shows differences between coastal and inland areas. These variations provide a basis for examining whether physical accessibility to essential facilities is statistically associated with differences in village development. Understanding such relationships is relevant to infrastructure planning and the equitable distribution of public services across geographically diverse rural areas.

This study examines the relationship between spatial accessibility to educational, health, and economic facilities and village development, as measured by IDM scores, across 222 villages in Pidie Jaya Regency, Indonesia. Accessibility is quantified using the Closest Facility Network Analysis method in ArcGIS to calculate the shortest road-network distances from village settlement centers to seven categories of essential facilities: elementary schools, junior high schools, senior high schools, hospitals, community health centers, auxiliary health posts, and markets. Multiple linear regression is used to estimate the statistical relationships between these accessibility measures and IDM scores.

By integrating network-based accessibility measures with a multidimensional village development indicator, the study may provide empirical evidence on geographical accessibility patterns associated with disparities in village development. The findings are expected to inform infrastructure policy and management by supporting the identification of underserved areas and the prioritization of essential-service improvements in Pidie Jaya Regency.

THEORETICAL FRAMEWORK

Village development is a multidimensional process involving improvements in social well-being, economic conditions, environmental sustainability, and access to essential public services. In Indonesia, the Village Development Index (*Indeks Desa Membangun*, IDM) provides an institutional framework for assessing these dimensions through three composite indices: the Social Resilience Index (*Indeks Ketahanan Sosial*, IKS), the Economic Resilience Index (*Indeks Ketahanan Ekonomi*, IKE), and the Environmental Resilience Index (*Indeks Ketahanan Lingkungan*, IKL).

According to Regulation of the Minister of Villages, Development of Disadvantaged Regions, and Transmigration No. 2 of 2016, IDM is calculated as the average of these three indices. IKS encompasses education, health, social capital, and settlement conditions; IKE reflects economic resilience; and IKL represents environmental and disaster-related conditions. Accordingly, IDM captures broader dimensions of village development rather than household poverty directly. This multidimensional perspective is consistent with Lathifah et al. (2024), who assessed rural development status in Karawang Regency using scalogram analysis based on the availability and accessibility of educational, healthcare, economic, and environmental facilities.

Accessibility is a basic concept in spatial planning and infrastructure development and refers to the ease with which people or locations can reach services, activities, and opportunities. It is influenced by the spatial distribution of destinations, transportation connectivity, and travel characteristics between origins and destinations.

Infrastructure availability should therefore be distinguished from geographical accessibility because the presence of a facility does not necessarily mean that it can be reached easily. Novianto et al. (2020) highlighted this distinction by identifying limitations in the use of IDM classifications to detect villages experiencing substantial difficulties in educational access. They argued that accessibility assessments should consider both facility availability and the difficulty of reaching those facilities. Also, Nurhidayani et al. (2018) examined the relationship between road-network accessibility and village development in Tambun Selatan, Bekasi Regency, and reported a positive correlation between their accessibility and development indices. These findings provide a conceptual and empirical basis for assessing physical accessibility separately from broader village development classifications. In the present study, accessibility is operationalized as the shortest road-network distance from village settlement centers to the nearest essential service facilities.

Educational accessibility is conceptually associated with the social resilience dimension of village development because access to schools supports educational participation and human capital development. The IDM framework incorporates accessibility to elementary, junior high, and senior high schools within its social resilience indicators. Ayyumi et al. (2022) demonstrated the relevance of school distribution and geographical service coverage in assessing educational accessibility, while Susanti et al. (2020) highlighted continuing educational challenges in rural and remote areas of Indonesia. Accordingly, this study measures educational accessibility using the shortest road-network distances to elementary schools (X1), junior high schools (X2), and senior high schools (X3). Longer distances may create geographical barriers to education, although actual access also depends on transportation availability, household resources, and school quality. Moreover, the continuous distance measures used in this study are not identical to the accessibility indicators incorporated into IDM, so their statistical relationships should be interpreted very carefully.

Healthcare accessibility is an important component of village development because access to medical services contributes to community health and social resilience. The IDM framework includes healthcare-related indicators reflecting the availability and accessibility of essential services. Wenang et al. (2021) documented geographical disparities in healthcare availability and utilization among rural and disadvantaged populations in Indonesia, while Mahendradhata et al. (2017) discussed challenges related to healthcare infrastructure and service provision within the Indonesian health system. In this study, healthcare accessibility is measured using the shortest road-network distances to hospitals (X4), community health centers or *Puskesmas* (X5), and auxiliary health posts or *Pustu* (X6). As these facilities perform different healthcare functions, their relationships with village development also differ. Nevertheless, geographical distance represents only one dimension of healthcare accessibility, as service quality, transportation availability, and affordability also influence the ability of residents to obtain care.

Economic accessibility refers to the ability of communities to reach markets and other locations that support economic activity. In rural areas, market access facilitates the exchange of agricultural products, household consumption, and income-generating opportunities. Emran and Hou (2013) examined the relationship between market accessibility and household consumption in

rural China, demonstrating the relevance of geographical access to economic welfare. Similarly, Suppulangi et al. (2025) identified significant relationships between accessibility and community economic conditions in Paliorong Village. In the IDM framework, market accessibility is related to economic resilience. Accordingly, the shortest road-network distance to the nearest market (X7) is used as an indicator of physical economic accessibility. However, market distance does not fully represent economic potential since transportation costs, productive resources, trading networks, and local socioeconomic conditions also shape economic access.

The conceptual relationship between accessibility and village development also requires careful consideration of measurement characteristics. Because IDM incorporates indicators related to access to educational, healthcare, and economic services, some explanatory variables in this study are conceptually related to components of the dependent variable. This creates the possibility of measurement overlap, whereby part of the observed statistical association may reflect shared underlying dimensions rather than entirely independent relationships between infrastructure accessibility and broader development conditions.

However, the shortest road-network distances calculated in this study are not necessarily equivalent to the indicators used in the official IDM assessment. The analysis therefore aims to identify statistical associations between geographically measured accessibility and overall village development rather than to estimate causal effects. These relationships are examined using multiple linear regression, while recognizing that institutional, socioeconomic, environmental, and other unobserved characteristics may also contribute to variation in village development across Pidie Jaya.

METHODOLOGY

Study Area

The study was conducted in Pidie Jaya Regency, Aceh Province, Indonesia. Pidie Jaya was established as a separate administrative regency from Pidie Regency in 2007. It covers an area of 952.11 km² and had a population of 164,361 in 2023. The regency comprises eight subdistricts and 222 villages. All 222 villages were included in the analysis; therefore, the study uses the full village population rather than a sample of villages. The study area is shown in Figure 1.

Research Design

This study employed a quantitative cross-sectional research design integrating spatial network analysis and statistical modelling to examine the relationship between accessibility to essential service facilities and village development in Pidie Jaya Regency, Indonesia. The analysis was conducted in two sequential stages.

First, spatial accessibility was assessed using the Closest Facility Network Analysis method in ArcGIS to calculate the shortest road-network distances from village settlement centers to the nearest educational, healthcare, and economic facilities. Road-network distances were used instead of straight-line distances to better represent accessibility through the existing transportation network. The calculated distances were initially expressed in meters (m) for descriptive accessibility classification and subsequently converted to kilometers (km) for regression analysis. Accordingly, all seven explanatory variables (X1–X7) were measured in kilometers.

Second, ordinary least squares (OLS) multiple linear regression was used to examine the associations between

accessibility distances and village development, measured using continuous Village Development Index (IDM) scores. The explanatory variables comprised distances to elementary schools (X1), junior high schools (X2), senior high schools (X3), hospitals (X4), community health centers (X5), auxiliary health posts (X6), and markets (X7).

Model diagnostics included the Shapiro–Wilk test to assess residual normality, the Breusch–Pagan test to assess heteroskedasticity, and variance inflation factors (VIFs) to assess multicollinearity. Because heteroskedasticity was detected, HC3 heteroskedasticity-robust standard errors were used for coefficient inference while retaining the OLS coefficient estimates. Individual coefficients were evaluated using robust *t*-tests, while the coefficient of determination (R^2) was used to indicate the proportion of variation in IDM scores accounted for by the model.

Each unstandardized regression coefficient represents the estimated difference in IDM score associated with a one-kilometer increase in distance to the corresponding facility, holding the other explanatory variables constant. Given the cross-sectional design, the estimated coefficients were interpreted as statistical associations rather than causal effects.

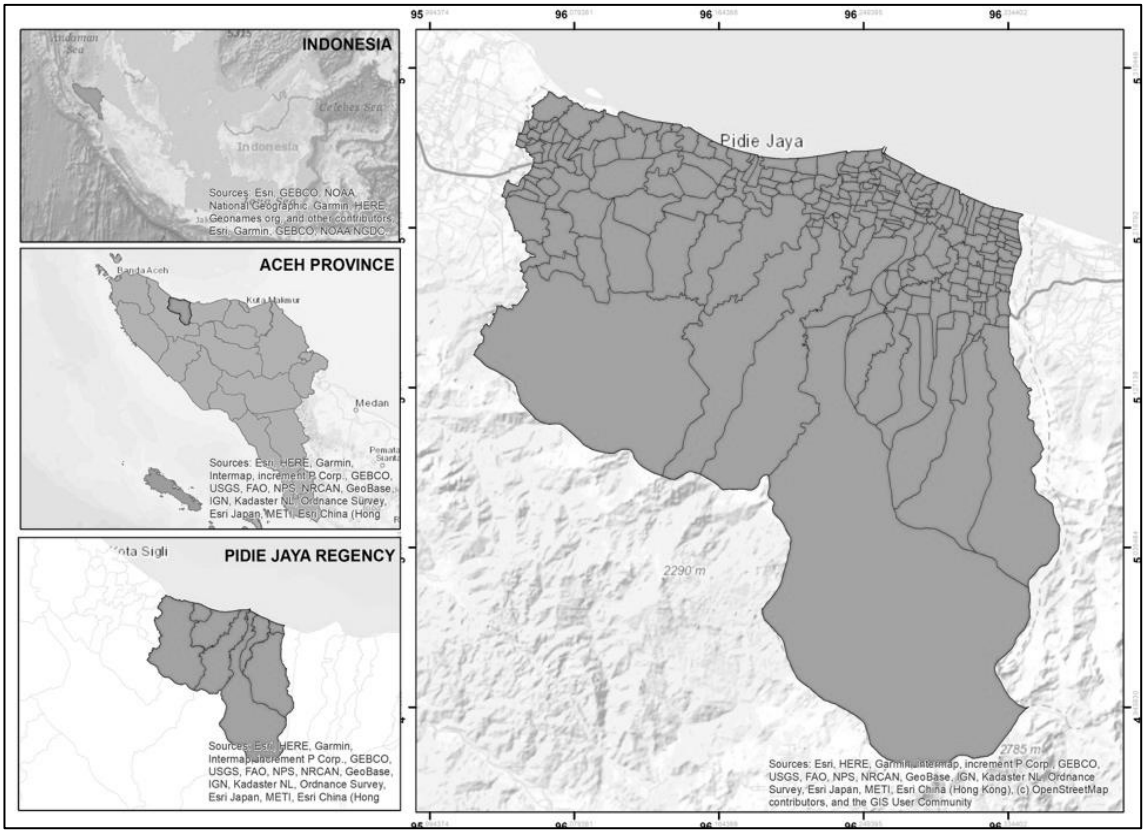


Figure 1. Study area of Pidie Jaya Regency, Aceh, Indonesia

Source: Geospatial Information Agency of Indonesia (BIG) and PUPR, 2023

Data and Data Sources

This study used secondary spatial and statistical data obtained from Statistics Indonesia (*Badan Pusat Statistik*, BPS), the Public Works and Housing Agency (*Pekerjaan Umum dan Perumahan Rakyat*, PUPR), and the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration. The datasets included administrative boundaries, road networks, village settlement locations, the geographical distribution of educational facilities (elementary, junior high, and senior high schools), healthcare facilities (hospitals, community health centers or *Puskesmas*, and auxiliary health posts or *Pustu*), economic facilities (markets), and village-level IDM scores for 2023. The spatial datasets were used as inputs for the network analysis, while the resulting accessibility measurements were subsequently integrated with the IDM scores for statistical analysis.

The dependent variable (Y) was the continuous IDM score, a composite indicator consisting of the Social Resilience Index (IKS), Economic Resilience Index (IKE), and Environmental Resilience Index (IKL). IDM scores range from 0 to 1, with higher values indicating more advanced levels of village development. Unlike income- or consumption-based poverty indicators, IDM measures multidimensional village development and was not interpreted as a direct measure of poverty.

The study population comprised all 222 villages across eight subdistricts in Pidie Jaya Regency. A census approach was adopted, with all villages included as units of analysis to provide complete geographical coverage of the study area. This approach eliminated the need for sample selection and enabled village-level comparisons of spatial accessibility and development conditions throughout the regency.

RESULTS

Spatial Accessibility to Educational, Healthcare, and Economic Facilities

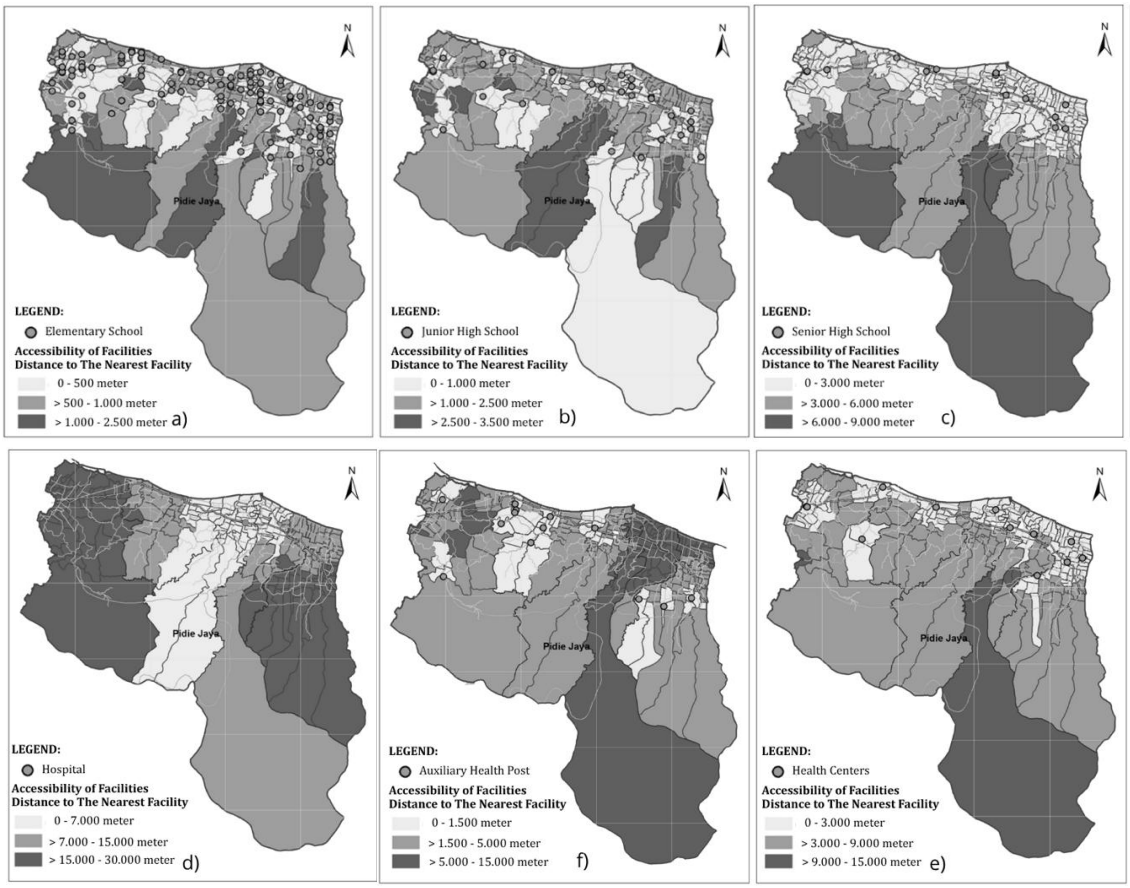
Spatial accessibility to educational, healthcare, and economic facilities varies considerably across Pidie Jaya Regency. Results from the Closest Facility Network Analysis show that educational facilities generally have better road-network accessibility than healthcare and economic facilities. Accessibility was classified by comparing village-to-facility network distances with the adopted reference distances for each facility type. Villages located within the relevant reference distance were classified as accessible, whereas villages located beyond the threshold were classified as not accessible.

The results reveal substantial spatial disparities in access to educational facilities. Elementary schools show the highest level of accessibility, with 210 villages (94.6%) located within the 1,000 m reference distance. Of these, 125 villages (56.3%) are located within 500 m and 85 villages (38.3%) are located between 500 and 1,000 m. The remaining 12 villages (5.4%) are located beyond the 1,000 m threshold.

Table 1. Results of the closest facility network analysis

No	Facility Category and Type		Reference Distance	Network Analysis Results			
				Accessible		Not Accessible	
				Number of Villages	Percent (%)	Number of Villages	Percent (%)
1.	Educational Facilities	Elementary	1.000 m	210	94,6%	12	5,4%
		Junior High School	1.000 m	97	43,7%	125	56,3%
		Senior High School	3.000 m	154	69,4%	68	30,6%
2.	Health Facilities	Hospital	7.000 m	50	22,5 %	172	77,5 %
		Community Health Center	3.000 m	117	52,7 %	105	47,3%
		Auxiliary Health Post	1.500 m	40	18%	182	82%
3.	Economic Facilities	Market	1.000 m	25	11,3%	197	88,7%

Accessibility to junior high schools is considerably low. Ninety-seven villages (43.7%) are located within 1,000 m of the nearest junior high school, while 115 villages (51.8%) are located between 1,000 and 2,500 m, and 10 villages (4.5%) are located more than 2,500 m away. For senior high schools, 154 villages (69.4%) are located within the 3,000 m reference distance, whereas 68 villages (30.6%) exceed this threshold. These findings indicate that elementary schools are more accessible across the regency, while substantial geographical accessibility gaps remain for junior and senior high schools.



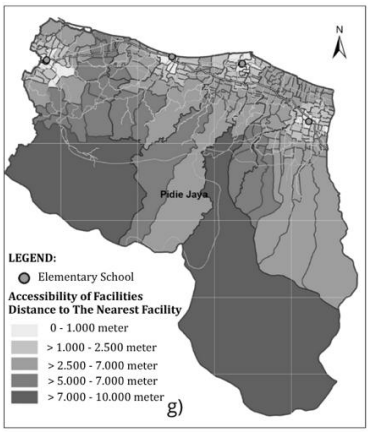


Figure 2. Spatial accessibility to educational, health, and economic facilities in Pidie Jaya Regency

Source: Geospatial Information Agency of Indonesia (BIG) and PUPR, 2023

Healthcare facilities also show substantial variation in geographical accessibility. Only 50 villages (22.5%) are located within the adopted 7,000 m reference distance of the nearest hospital, while 172 villages (77.5%) are located beyond this threshold. Accessibility to *Puskesmas* is higher, with 117 villages (52.7%) located within 3,000 m and 105 villages (47.3%) located beyond this distance. Auxiliary health posts (*Pustu*) show the lowest accessibility coverage among the healthcare facilities examined, with only 40 villages (18.0%) located within the 1,500 m reference distance and 182 villages (82.0%) located beyond it. These results indicate substantial disparities in road-network access to healthcare services, particularly hospitals and auxiliary health posts.

Market facilities show the lowest accessibility coverage among the seven facility categories analyzed. Only 25 villages (11.3%) are located within the adopted 1,000 m reference distance of the nearest market, whereas 197 villages (88.7%) are located beyond this threshold. This pattern indicates considerable geographical separation between many village settlements and market facilities and may be associated with greater travel requirements for accessing goods and economic activities. Overall, the lowest proportions of villages meeting the adopted reference distances are observed for markets, auxiliary health posts, and hospitals.

The spatial distribution of 2023 Village Development Index (IDM) categories shows a marked north–south pattern across Pidie Jaya Regency (Figure 3). Villages categorized as advanced, independent, and developing are concentrated mainly in the northern and central coastal areas, whereas lagging and severely lagging villages are more prevalent in the southern inland areas.

These spatial patterns indicate geographical disparities in village development across the regency. Although the southern areas also appear to have more limited road-network connectivity and more challenging terrain, the descriptive map alone does not establish that these geographical characteristics cause lower IDM status. The statistical relationship between accessibility and IDM scores is therefore examined using multiple linear regression.

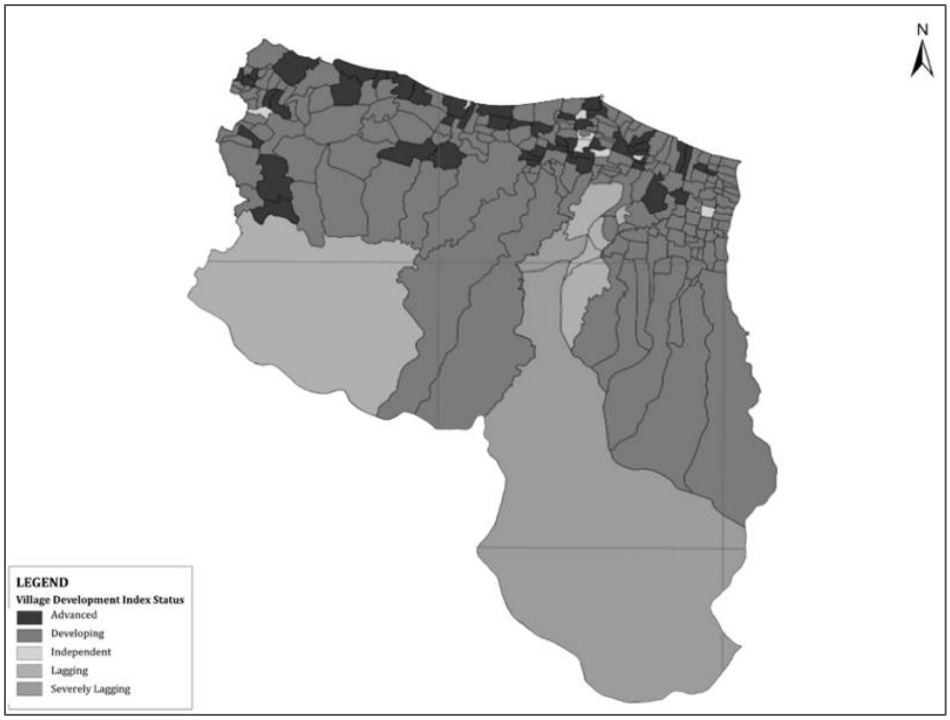


Figure 3. Spatial distribution of the village development index in Pidie Jaya Regency

Source: Geospatial Information Agency of Indonesia (BIG), PUPR, and the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration, 2023.

Multiple Linear Regression Results

Multiple linear regression analysis was used to examine the relationships between road-network distances to seven categories of educational, healthcare, and economic facilities and Village Development Index (IDM) scores. The coefficient of determination (R^2) was used to assess the proportion of variation in IDM scores accounted for by the accessibility variables. The model summary is presented in Table 2.

The model accounts for 22.5% of the variation in IDM scores ($R^2 = 0.225$), while the adjusted R^2 is 0.199. This result indicates that spatial accessibility is associated with variation in village development, although a substantial proportion of the variation remains attributable to factors not included in the model, including socioeconomic, institutional, environmental, and other characteristics.

From a broader socioeconomic perspective, limited access to essential services may also be associated with greater vulnerability among less-developed villages. Khan et al. (2006) similarly emphasized the importance of geographical conditions in shaping poverty and health outcomes in disadvantaged areas. However, the present study examines village development rather than poverty directly, and the regression results should therefore be interpreted in relation to IDM scores rather than as direct evidence of poverty outcomes.

Table 2. Results of the coefficient of determination test

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.474[a]	.225	.199	.05361
Predictors: X_1, X_2, X_3, X_4, X_5, X_6, and X_7				
Dependent variable: IDM score (Y)				

Table 3. Multiple linear regression results with HC3 robust standard errors

	Variable	B	Robust Std. Error (HC3)	Robust t	Sig.	Tolerance	VIF
1	(Constant)	.758567	.012521	60.583	<.001	-	-
	X_1	-.012291	.012503	-.983	.327	.841	1.190
	X_2	.001373	.007018	.196	.845	.742	1.348
	X_3	-.016463	.003818	-4.312	<.001	.377	2.650
	X_4	-.001772	.000606	-2.924	.004	.871	1.148
	X_5	.001017	.002722	.374	.709	.402	2.486
	X_6	-.004398	.001464	-3.004	.003	.931	1.075
	X_7	.002165	.002288	.946	.345	.869	1.150

X_1 = distance to elementary school; X_2 = distance to junior high school; X_3 = distance to senior high school; X_4 = distance to hospital; X_5 = distance to community health center; X_6 = distance to auxiliary health post; X_7 = distance to market. All distance variables are measured in kilometers.

Based on the estimated coefficients, the regression equation is:

$$Y = a + b1X_1 + b2X_2 + b3X_3 + b4X_4 + b5X_5 + b6X_6 + b7X_7$$

$$IDM = 0.758567 - 0.012291X_1 + 0.001373X_2 - 0.016463X_3 - 0.001772X_4 + 0.001017X_5 - 0.004398X_6 + 0.002165X_7$$

The intercept of 0.7586 represents the predicted IDM score when all seven accessibility distances are zero and therefore serves primarily as a mathematical reference point. The coefficients for distances to elementary schools (X_1), senior high schools (X_3), hospitals (X_4), and auxiliary health posts (X_6) are negative, whereas the coefficients for junior high schools (X_2), community health centers (X_5), and markets (X_7) are positive.

Based on HC3 robust standard errors, only distances to senior high schools (X_3; $p < 0.001$), hospitals (X_4; $p = 0.004$), and auxiliary health posts (X_6; $p = 0.003$) show statistically significant associations with IDM scores. Their negative coefficients indicate that, holding the other accessibility variables constant, greater road-network distances to these facilities are associated with lower IDM scores. Distances to elementary schools, junior high schools, community health centers, and markets are not statistically significant at the 5% level. These coefficients should therefore not be interpreted as evidence of meaningful positive or negative relationships. Overall, the regression results indicate statistical associations rather than causal effects.

Diagnostic tests were conducted to assess the assumptions and reliability of the OLS model. The Shapiro–Wilk test showed no statistically significant departure from residual normality ($W = 0.9936$, $p = 0.453$). In contrast, the Breusch–Pagan test indicated heteroskedasticity ($LM = 28.279$, $p < 0.001$). Accordingly, HC3 heteroskedasticity-robust standard errors were used to obtain more reliable coefficient inference under non-constant error variance. The multicollinearity assessment showed no evidence of severe multicollinearity, with VIF values ranging from 1.075 to 2.650.

DISCUSSION

The regression findings indicate that the relationship between spatial accessibility and village development differs across facility types. Accessibility to elementary schools (X_1) is not significantly associated with IDM scores. This result may partly reflect the extensive geographical coverage of elementary schools, as 94.6% of villages are located within the adopted reference distance. Such widespread coverage may limit variation in elementary-school accessibility across villages. However, this interpretation remains tentative because the regression does not directly test whether coverage levels explain the absence of statistical significance.

Accessibility to junior high schools (X_2) is also not significantly associated with IDM scores, despite more than half of the villages being located beyond the adopted reference distance. This suggests that road-network distance to junior high schools, considered independently of the other variables in the model, does not distinguish village development levels in a statistically significant manner. Other dimensions of educational access, including transportation availability, school capacity, household resources, and participation rates, may also be relevant but were not examined in this study. Novianto et al. (2020) similarly showed that IDM classifications do not necessarily correspond to actual difficulties in accessing educational facilities, reinforcing the distinction between geographical accessibility and broader measures of village development.

In contrast, distance to senior high schools (X_3) shows a statistically significant negative association with IDM scores. Holding the other accessibility variables constant, a one-kilometer increase in distance to the nearest senior high school is associated with an estimated decrease of 0.016463 in the IDM score. This association may reflect the more spatially concentrated distribution of senior high schools compared with elementary schools, although the study does not directly test the mechanisms underlying this relationship. Greater distance may be associated with higher travel requirements and transportation burdens for residents of more remote villages. Suppulangi et al. (2025) also identified a significant relationship between educational accessibility and economic conditions in a rural Indonesian context. Although the indicators and study designs differ, the studies highlight the relevance of educational accessibility to rural development conditions.

Healthcare accessibility also shows differing relationships across facility types. Distance to community health centers (*Puskesmas*, X_5) is not significantly associated with IDM scores. This finding suggests that geographical distance alone may not adequately capture variation in access to these services. Other factors, such as transportation availability, service capacity, healthcare personnel, affordability, and patterns of service utilization, were not included in the present analysis and may also influence effective healthcare access.

By contrast, distances to hospitals (X_4) and auxiliary health posts (*Pustu*, X_6) show statistically significant negative associations with IDM scores. Holding the other explanatory variables constant, a one-kilometer increase in distance to the nearest hospital is associated with an estimated decrease of 0.001772 in IDM score, while a one-kilometer increase in distance to the nearest auxiliary health post is associated with an estimated decrease of 0.004398. These relationships indicate that villages located farther from these facilities tend to have lower development scores. Wenang et al. (2021) documented geographical disparities in healthcare accessibility in rural Indonesia, while Gaspersz (2023) identified relationships between public-service availability and village development status. These studies provide relevant context for interpreting the link between healthcare accessibility and village development observed in Pidie Jaya.

Furthermore, distance to the nearest market (X_7) is not significantly associated with IDM scores. This suggests that distance to formal markets alone may not adequately represent economic accessibility at the village level. Rural households may engage with other forms of economic infrastructure and exchange, including local shops, small-scale traders, informal markets, and direct transactions. However, these mechanisms were not measured in the present study and therefore remain possible explanations rather than demonstrated findings. Lathifah et al. (2024) examined the relationship between facility availability, accessibility, and village development classifications in Karawang Regency. Their findings provide a useful comparison, although the present study differs by using road-network distances and continuous IDM scores rather than a weighted scalogram approach.

Taken together, the findings indicate that spatial accessibility is associated with village development in a selective rather than uniform manner. Significant relationships are observed for senior high schools, hospitals, and auxiliary health posts, whereas the other facility categories do not show statistically significant associations. This variation suggests that the relationship between infrastructure accessibility and village development depends on facility type and cannot be inferred solely from the proportion of villages located within adopted service-distance thresholds.

From an infrastructure planning perspective, villages with relatively limited access to senior high schools, hospitals, and auxiliary health posts may warrant closer consideration in spatial planning and service-delivery assessments. Potential responses may include evaluating road connectivity, transportation services, facility distribution, and other barriers to access. However, the regression results alone do not establish that expanding facilities or reducing travel distances would directly increase IDM scores. The intervention would require further assessment of service demand, facility capacity, cost, feasibility, and other local conditions.

The absence of statistically significant relationships for elementary schools, junior high schools, community health centers, and markets should likewise not be interpreted as evidence that these facilities are unimportant. The regression model accounts for 22.5% of the variation in IDM scores, indicating that substantial variation remains associated with factors outside the model. Village development planning should therefore also consider socioeconomic, institutional, environmental, and other contextual conditions. Moreover, as some IDM components incorporate service accessibility dimensions, the observed relationships

should be interpreted with awareness of the potential measurement overlap identified in the theoretical framework. Overall, the findings imply association rather than causality.

CONCLUSION

This study examined the relationship between road-network accessibility to educational, healthcare, and economic facilities and village development in Pidie Jaya Regency. The findings show substantial variation in geographical accessibility across facility types. Elementary schools have relatively extensive coverage, whereas hospitals, auxiliary health posts, and markets remain less accessible to many villages. The regression model accounts for 22.5% of the variation in Village Development Index (IDM) scores. Greater distances to senior high schools, hospitals, and auxiliary health posts are significantly associated with lower IDM scores, whereas distances to elementary schools, junior high schools, community health centers, and markets show no statistically significant associations.

These findings support the use of road-network accessibility analysis as a tool for identifying underserved villages and informing spatially targeted infrastructure and service planning. Local and provincial authorities may consider evaluating transportation connectivity, strengthening existing service provision, and assessing the need for additional facilities based on local demand, facility capacity, and infrastructure conditions. However, because the observed relationships are associative rather than causal, the regression results alone do not establish that reducing travel distances or constructing additional facilities would directly increase IDM scores. Proposed interventions therefore require further assessment before implementation.

Overall, the study provides evidence of geographical disparities in access to essential services and demonstrates how network-based accessibility measures can complement village development indicators in supporting more equitable infrastructure planning.

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