School Accessibility and the Spatial Connectivity of *Senior High School* Services in Malang City, Indonesia: A Sequential GIS Service-Area and PLS-SEM Analysis

Maria Christina Endarwati
Program Studi Perencanaan Wilayah dan Kota ITN Malang, Indonesia
mc.mendarwati@lecturer.itn.ac.id
Tjokarda Nirarta Samadhi
Program Studi Perencanaan Wilayah dan Kota ITN Malang, Indonesia
tjokordanirata@lecturer.itn.ac.id
Agustina Nurul
Program Studi Perencanaan Wilayah dan Kota ITN Malang, Indonesia
Agustina.nurul.h@lecturer.itn.ac.id

Corresponding Author: Maria Christina Endarwati

Article history: Received: March 13, 2026 | Revised: April 15, 2026 | Available Online: June 30, 2026

Abstract

Equal access to public secondary education remains a challenge in Indonesia's rapidly urbanizing cities. Most planning studies rely either on objective spatial coverage metrics or on user perceptions, so the link between territorial service gaps and the connectivity students experience remains under-researched. This study integrates both perspectives to evaluate *Senior High School* (SMAN) provision in Malang, and to test whether educational service integration mediates the links among school accessibility, regional facility availability, student mobility, and perceived spatial connectivity. A sequential explanatory design was used for a road-network service-area analysis at a 3,000 m threshold, in accordance with SNI 03-1733-2004, to map territorial coverage. Partial least squares structural equation modeling (PLS-SEM) was then estimated using survey data from 200 purposively sampled SMAN students between March and May 2025. SMAN services covered 66.26% of the city; one-third (33.74%) was unserved. Klojen was fully covered, while gaps were concentrated in Sukun (the highest proportion), Kedungkandang, and Blimbing. Accessibility ($\beta = 0.309$), facility availability ($\beta = 0.339$), mobility ($\beta = 0.260$; all $p < 0.001$), and service integration ($\beta = 0.167$, $p = 0.003$) were positively associated with perceived spatial connectivity ($R^2 = 0.582$). Integration partially mediated the effects of accessibility and facility availability, but not mobility, suggesting that institutional inputs operate through institutional coordination, whereas individual mobility does not. Because the sample was purposive and self-reported, the findings are exploratory. Educational equity policy should be district-specific and combine coverage expansion, road network improvements, and the coordination of school zoning with transport.

Keywords: spatial connectivity; school accessibility; educational facilities; student mobility; educational service integration

Introduction

Unequal access to schooling remains a persistent feature of urban education systems. UNESCO (2022) estimates that about 244 million children and adolescents worldwide lack adequate access to education, and more than 30% of students in urban areas of developing countries face limited access to educational facilities.[1] Recent work treats this problem as much spatial as pedagogical: where schools sit, how well they connect to residential areas, and how quality is distributed across the territory shape who can actually use them.[2] In this literature, educational spatial connectivity refers to the degree to which students' residences, schools, and supporting services are linked through road networks, travel distance and time, and transport availability.[3]

Indonesian secondary cities are a useful but understudied setting for this question. In Malang City, East Java, our GIS service-area analysis shows that SMAN services cover 7,359.07 ha, or 66.26% of the city, while 3,748.58 ha (33.74%) lies beyond the 3,000 m network threshold set by the national planning standard. The gap is district-differentiated: Sukun has the highest unserved proportion, Kedungkandang has the largest unserved area in absolute terms, and Blimbing has a substantial share of both. Access to state upper-secondary education in Malang is therefore a service distribution and planning problem as much as an enrollment problem, because uneven coverage limits which households can access public schooling and interacts with the zoning-based admission policy.

Most spatial studies of educational access examine direct relationships between school location, accessibility, and inequality. Cobb, Han et al., and Sharma and Patil treat spatial accessibility and service coverage as core determinants of educational equity. Still, they do not ask how accessibility translates into system-level connectivity through the coordination of educational services.[4] Research on student mobility explains how

[1] World Bank, "World Development Report 2021: Data for Better Lives" (World Bank, 2021).

[2] C D Cobb, "Geospatial Analysis: A New Window into Educational Equity, Access, and Opportunity," *Review of Research in Education* 44, no. 1 (2020): 97–129, https://doi.org/10.3102/0091732X20907362; J Rueda, F Moura, and V Cantillo, "Quality of Schools and Inequalities in Access: A Socio-Territorial Analysis," *Applied Geography* 188 (2026): 103909, https://doi.org/10.1016/j.apgeog.2026.103909; G Sharma and G R Patil, "Spatial and Social Inequities for Educational Services Accessibility: A Case Study for Schools in Greater Mumbai," *Cities* 122 (2022): 103543, https://doi.org/10.1016/j.cities.2021.103543.

[3] Y Guo and X Li, "Regional Inequality in China's Educational Development: An Urban-Rural Comparison," *Heliyon* 10, no. 4 (2024): e26249, https://doi.org/10.1016/j.heliyon.2024.e26249.

[4] Cobb, "Geospatial Analysis: A New Window into Educational Equity, Access, and Opportunity"; Z Han et al., "Improving Educational Equity by Maximizing Service Coverage in Rural Changyuan, China: An Evaluation-Optimization-Validation Framework Based on Spatial Accessibility to Schools," *Applied Geography* 152 (2023): 102891, https://doi.org/10.1016/j.apgeog.2023.102891.

students move across space to reach schooling, yet treats mobility as an individual access mechanism rather than part of an integrated service system.[5] Work that addresses institutions, such as Agostinelli et al.,[6] on the institutional determinants of educational access and Álvarez-Rivadulla et al.[7] on college integration, does not test service integration as a mediating mechanism in a spatial connectivity model. Whether accessibility, facility provision, and mobility affect educational spatial connectivity directly, or whether their effects run partly through the integration of educational services, therefore, remains unclear. The distinction matters because physical reachability does not guarantee usable service delivery; a school can be nearby yet still poorly connected to transport, support services, and neighboring institutions.

This study makes three contributions. *First*, it operationalizes educational service integration as a measurable mediating construct in a spatial connectivity model, rather than treating integration as a background assumption. *Second*, it pairs a GIS service-area analysis with a perception-based structural model in a single Indonesian secondary city. The two strands are not linked at the individual level, but form a sequential design: the GIS analysis establishes the territorial context, and the PLS-SEM analysis examines students' perceptions of that context. *Third*, it provides evidence relevant to current Indonesian debates on school zoning, transport coordination, and facility distribution in medium-sized cities, where research is sparser than in Jakarta and Surabaya. The study pursues three objectives: (1) to map and quantify the spatial coverage of SMAN services in Malang City and identify underserved districts; (2) to estimate the associations of perceived school accessibility, facility availability, and student mobility with perceived educational spatial connectivity; and (3) to test whether educational service integration mediates these associations.

[5] G Custers, M Das, and G Engbersen, "Change or Stability in Educational Inequalities? Educational Mobility and School Effects in the Context of a Major Urban Policy," *Urban Studies* 60, no. 14 (2023): 2852–73, https://doi.org/10.1177/00420980231162774; R Scandurra, A Zancajo, and X Bonal, "Opting out of Neighbourhood Schools: The Role of Local Education Markets in Student Mobility," *Population, Space and Place* 28, no. 5 (2022): e2542, https://doi.org/10.1002/psp.2542; X Zhang, E S Lim, and M Chen, "Promoting Sustainable Urban Mobility: Factors Influencing e-Bike Adoption in Henan Province, China," *Sustainability* 16, no. 22 (2024): 10136, https://doi.org/10.3390/su162210136.

[6] F Agostinelli, M Luflade, and P Martellini, "On the Spatial Determinants of Educational Access," NBER Working Paper No. 32246 (National Bureau of Economic Research, 2024), https://doi.org/10.3386/w32246.

[7] M J Álvarez-Rivadulla et al., "College Integration and Social Class," *Higher Education* 84, no. 3 (2022): 647–69, https://doi.org/10.1007/s10734-021-00793-6.

The hypotheses draw on three perspectives: accessibility theory, spatial interaction theory, and education system theory.

Accessibility theory holds that the use of public services depends on the physical presence of facilities and on how easily users can reach them, given distance, travel time, transport availability, and network conditions.[8] For SMAN services, students who can more easily reach schools should be better connected to educational services and support facilities. Educational facilities such as classrooms, libraries, and laboratories also function as service nodes: when they are adequate and evenly distributed, the links among students, schools, and educational resources strengthen; when they are skewed, spatial gaps compound educational inequality.

H1. School accessibility positively affects spatial connectivity in education. H2. The availability of regional educational facilities positively affects spatial connectivity in education. Spatial interaction theory emphasizes linkages between locations through movement, networks, and functional ties. In education, student mobility connects residential areas with schools and other services; students who can move across areas can draw on educational resources beyond their immediate neighborhood.

H3. Student educational mobility positively affects spatial connectivity in education. The theory of the education system views education as a set of interdependent components: schools, students, facilities, transport support, institutional coordination, and policy instruments. Systems perform better when these components reinforce one another,[9] and network accounts of public services suggest that stronger ties among service nodes extend service reach.[10] Educational service integration, defined here as the degree to which schools, facilities, and supporting services operate as a coordinated whole, should therefore improve connectivity.

H4. Educational service integration positively affects spatial connectivity in education. These perspectives also imply antecedents of integration. Easier access to

[8] P Bhatt et al., "The Role of Educational Facilities and Community Engagement in Achieving SDG 4: A Structural Model Evaluation of Northern India Educational System," *Sage Open* 16, no. 1 (2026), https://doi.org/10.1177/21582440261416745; B van Wee, "Accessibility and Equity: A Conceptual Framework and Research Agenda," *Journal of Transport Geography* 104 (2022): 103421, https://doi.org/10.1016/j.jtrangeo.2022.103421.

[9] M Sanchez, E Exposito, and J Aguilar, "Industry 4.0: Survey from a System Integration Perspective," *International Journal of Computer Integrated Manufacturing* 33, no. 10–11 (2020): 1017–41, https://doi.org/10.1080/0951192X.2020.1775295.

[10] J Scott, *Social Network Analysis*, 4th ed. (Sage, 2020), https://doi.org/10.4135/9781529716597.

schools makes coordination among institutions, facilities, and student services more feasible and allows students to benefit from services delivered as a system.[11] Complete and well-distributed facilities provide the material basis for linking instruction, student support, extracurricular activity, and coordination, whereas scarcity fragments delivery.[12] Mobility may feed integration, since mobile students can engage services beyond their residential area. The transport and social-exclusion literature cautions, however, that individual mobility is bounded by cost, time, and transport supply, and translates into system-level coordination only when the service system itself is organized to absorb it.[13]

H5. School accessibility positively affects the integration of educational services. H6. The availability of regional educational facilities has a positive effect on educational service integration H7. Student educational mobility positively affects the integration of educational services. Beyond direct paths, education system theory suggests that accessibility and facility provision influence connectivity, in part, by enabling integration: institutional inputs create the conditions under which coordinated delivery becomes consequential. Mobility could contribute to connectivity through the same pathway, but the mechanism is theoretically weaker because individual movement does not, by itself, produce institutional coordination.[14]

H8. Educational service integration mediates the effect of school accessibility on educational spatial connectivity. H9. Educational service integration mediates the effect of the availability of regional educational facilities on educational spatial connectivity. H10. Educational service integration mediates the effect of student educational mobility on educational spatial connectivity.

[11] OECD, "Education Policy Outlook 2023" (OECD Publishing, 2023); van Wee, "Accessibility and Equity: A Conceptual Framework and Research Agenda."
[12] E A Assefa, "Infrastructure Matters: How School Facilities Influence Quality Education," *The Journal of Quality in Education* 16, no. 27 (2026): 73–95, https://doi.org/10.37870/joqie.v16i27.520; UNESCO, "Global Education Monitoring Report 2022" (UNESCO Publishing, 2022); Y Xie and M Zhang, "Synergy of Higher Education Resources and Digital Infrastructure Construction in China: Regional Differences, Dynamic Evolution and Trend Forecasting," *PLOS ONE* 19, no. 6 (2024): e0304613, https://doi.org/10.1371/journal.pone.0304613.
[13] D Banister, *Transport and Mobility Transitions* (Edward Elgar Publishing, 2021); K A Cagney et al., "Urban Mobility and Activity Space," *Annual Review of Sociology* 46, no. 1 (2020): 623–48, https://doi.org/10.1146/annurev-soc-121919-054848.
[14] OECD, "Education Policy Outlook 2023"; Zhang, Lim, and Chen, "Promoting Sustainable Urban Mobility: Factors Influencing e-Bike Adoption in Henan Province, China"; Cagney et al., "Urban Mobility and Activity Space."

The resulting structural model treats school accessibility, facility availability, and student mobility as exogenous variables, educational service integration as the mediator, and educational spatial connectivity as the endogenous variable.

Research Method

The study uses a sequential explanatory quantitative design with two strands. The first strand is a GIS road-network service-area analysis that maps the spatial distribution and coverage of SMAN services across Malang City and identifies served and unserved areas. The second strand is a PLS-SEM analysis of survey data that estimates the direct and indirect relationships among perceived school accessibility, facility availability, student mobility, service integration, and spatial connectivity. The spatial analysis shows where service gaps occur; the structural model examines how students experience access and which mechanisms are associated with their sense of connectivity. The two strands are complementary, not statistically integrated: respondent locations were not geocoded to service-area polygons, and no served-versus-unserved multigroup comparison was conducted.

Malang City covers 11,107.65 ha across five districts (Blimbing, Kedungkandang, Klojen, Lowokwaru, and Sukun). Secondary spatial data were compiled from the Malang City Regional Planning Agency (Bappeda Kota Malang) and OpenStreetMap. They comprised the coordinates of all SMAN operating in 2024, the city road network, and district administrative boundaries. Service-area polygons were generated in ArcGIS 10.8 (Network Analyst) using a 3,000 m road-network threshold, the distance standard for senior high school facilities in SNI 03-1733-2004 National Standardization Agency, 2004.[15] We used a network-based threshold rather than Euclidean buffers because it reflects actual travel paths along the street network.[16]

The population comprised students enrolled in SMAN in Malang City in the 2024/2025 academic year. Because no complete sampling frame was accessible, we used purposive sampling with three criteria: (1) active enrollment at an SMAN in Malang City, (2) regular commuting between home and school, and (3) the ability to describe school

[15] National Standardization Agency, "SNI 03-1733-2004: Guidelines for the Planning of Urban Residential Environments" (National Standardization Agency, 2004).

[16] A P Timpabi et al., "School Accessibility Assessment for Walking and Cycling; the Role of Street Connectivity and Land Use Variables," *Urban, Planning and Transport Research* 12, no. 1 (2024), https://doi.org/10.1080/21650020.2024.2312170.

accessibility, mobility, and facility conditions in their residential area. 200 valid responses were collected.

Sample-size adequacy was assessed against two thresholds. Cohen's power tables for multiple regression with four predictors indicate that 85 cases are required to detect a medium effect ($f^2 = 0.15$) with 80% power at $\alpha = 0.05$. The inverse-square-root method, Kock & Hadaya, requires 160 cases to detect a path coefficient of 0.20 with 80% power.[17] The sample of 200 exceeds both, but sits close to the practical minimum for a model with ten hypotheses; this is a limitation.[18] Because purposive sampling does not permit statistical generalization to the SMAN student population in Malang City, the significance tests below apply to the sample and the model tested, not to population-level inference.

A self-administered questionnaire measured five reflective constructs on five-point Likert scales (1 = strongly disagree, 5 = strongly agree). Because the GIS strand captures objective spatial conditions, the survey constructs are interpreted throughout as perceived conditions. Table 1 summarizes the constructs, their operational definitions, and the sources from which items were adapted; complete item wording is provided in Appendix A

Table 1.
Constructs, operational definitions, and measurement sources

Construct (code)	Operational definition	Items	Adapted from
School accessibility (SA)	Perceived ease of reaching school in terms of distance, travel time, transport availability, and route conditions	SA1-SA5	van Wee (2022); Timpabi et al. (2024)
Availability of regional educational facilities (AREF)	Perceived adequacy and distribution of classrooms, libraries, laboratories, and supporting infrastructure in the students' area	AREF1 - AREF5	UNESCO (2022); Xie & Zhang (2024)
Student educational mobility (SM)	Perceived capacity to move between home, school, and other educational services across areas	SM1-SM5	Scandurra et al. (2022); Custers et al. (2023)
Educational service integration (IES)	Perceived degree to which schools, facilities, transport support, and student services operate in a coordinated manner (e.g., aligned schedules, linked admission and support services, coordination between schools and transport provision)	IES1-IES5	Sanchez et al. (2020); Scott (2020); OECD (2023)

[17] N Kock and P Hadaya, "Minimum Sample Size Estimation in PLS-SEM: The Inverse Square Root and Gamma-Exponential Methods," *Information Systems Journal* 28, no. 1 (2018): 227–61, https://doi.org/10.1111/isj.12131.
[18] Kock and Hadaya, "Minimum Sample Size Estimation in PLS-SEM: The Inverse Square Root and Gamma-Exponential Methods."

Educational spatial connectivity (ESC)	Perceived strength of the links between the student's residence, school, and educational resources through networks and services	ESC1-ESC5	Guo & Li (2024); Sharma & Patil (2022)

Two experts in urban and regional planning and one in educational policy assessed content validity, reviewing the item pool for clarity, coverage, and relevance to the Malang City context. A pilot test with 30 SMAN students outside the main sample prompted revisions to items with unclear wording; pilot Cronbach's alpha values ranged from 0.78 to 0.86.

The final questionnaire was distributed between March and May 2025, online via Google Forms and in person at selected senior high schools. Participation was voluntary. Each respondent provided informed consent; respondents under 18 also provided parental or guardian consent.

Because all latent constructs were self-reported by the same respondents at a single time point, common method bias (CMB) posed a design risk. Two procedural safeguards addressed this: respondents remained anonymous, and items measuring the dependent and independent constructs were separated within the questionnaire.

The spatial strand overlaid 3,000 m service-area polygons on district boundaries and computed served and unserved areas in hectares and percentages, for each district and city-wide.

The survey strand was analyzed using PLS-SEM in SmartPLS, which is well-suited to prediction-oriented models with latent constructs and tolerates non-normal data.[19] The measurement model was evaluated for convergent validity (indicator loadings > 0.70; AVE > 0.50), internal consistency (Cronbach's alpha and composite reliability > 0.70), and discriminant validity (HTMT < 0.85).[20] CMB was assessed with Harman's single-factor test and the full collinearity approach (all inner VIF < 3.3; Kock, 2015). The structural model was evaluated using R^2, effect sizes f^2; Cohen,[21] predictive relevance (Q^2), and bootstrapped path coefficients (5,000 resamples; two-tailed, $t > 1.96$, $p < 0.05$).

[19] J F Hair et al., *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*, 3rd ed. (Sage, 2022).

[20] J Henseler, C M Ringle, and M Sarstedt, "A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling," *Journal of the Academy of Marketing Science* 43, no. 1 (2015): 115–35, https://doi.org/10.1007/s11747-014-8403-9.

[21] Jacob Cohen, *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. (Hillsdale, NJ: Lawrence Erlbaum Associates, 1988).

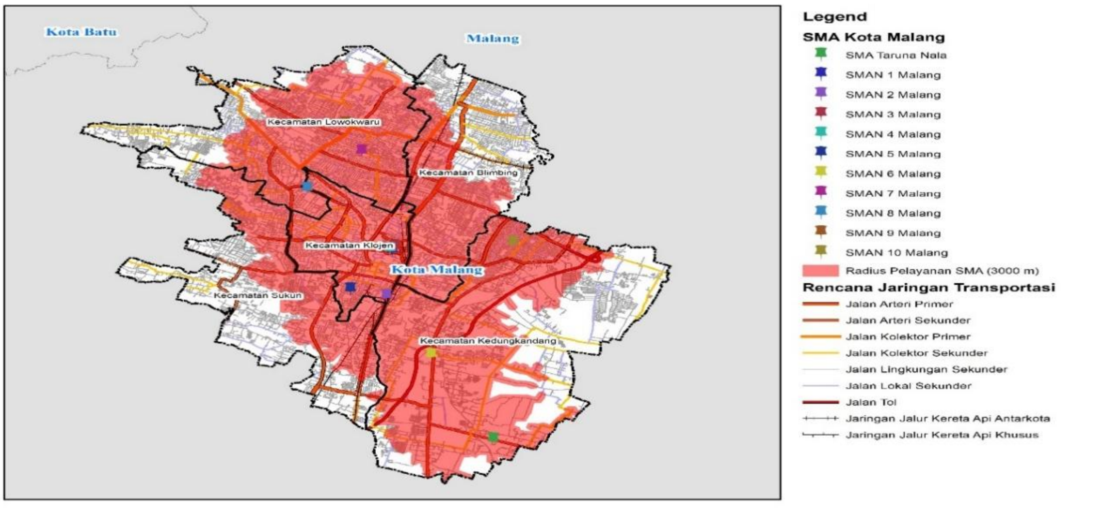
Mediation was tested via bootstrapped indirect effects, with mediation type classified per.[22]

Results

Spatial Coverage of SMAN Services

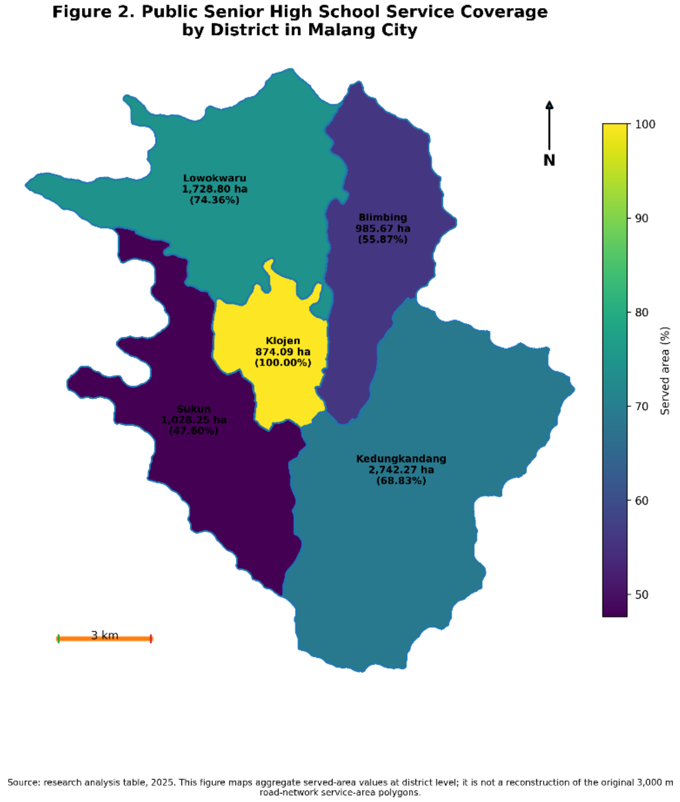
The service-area analysis shows uneven coverage. Of the city's 11,107.65 ha, 7,359.07 ha (66.26%) fall within a 3,000 m road-network service area of an existing SMAN, while 3,748.58 ha (33.74%) lie outside it (Figure 1). The gap is not uniformly distributed across districts (Figure 2). Sukun has the highest proportional gap, with 52.40% of its area unserved; Blimbing follows at 44.13%; Kedungkandang has a lower percentage but the largest absolute unserved area, 1,242.13 ha, owing to its extensive territory. Klojen, the city center, is fully covered.

Figure 1.
Spatial Distribution of *Senior High Schools*, 3000 m Service Area, and Transportation Network in Malang City



[22] Hair et al., *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*.

Figure 2.
Senior High School Service Coverage by District in Malang City



Measurement Model

All indicator loadings exceed 0.70, and all indicator VIF values remain below the critical threshold of 5 (ranging from 1.649 to 4.550), indicating no problematic collinearity among indicators (Table 2). All AVE values exceed 0.50 (Table 3), satisfying convergent validity, and Cronbach's alpha (0.856 to 0.939) and composite reliability (rho_c 0.897 to 0.953) exceed 0.70 for every construct, indicating adequate internal consistency. All HTMT ratios fall below the conservative 0.85 threshold, the highest being 0.632 between school accessibility and spatial connectivity, supporting discriminant validity (Table 4).

Table 2.
Indicator loadings and collinearity statistics

Construct	Indicator	Loading	VIF
Availability of regional educational facilities (AREF)	AREF1	0.836	2.013
	AREF2	0.852	3.224
	AREF3	0.846	2.940
	AREF4	0.849	2.603
	AREF5	0.905	4.550
Educational spatial connectivity (ESC)	ESC1	0.824	2.055
	ESC2	0.797	1.949

	ESC3	0.755	1.649
	ESC4	0.821	2.236
	ESC5	0.784	1.731
Educational service integration (IES)	IES1	0.870	2.726
	IES2	0.867	2.593
	IES3	0.804	2.120
	IES4	0.887	3.278
	IES5	0.887	3.280
School accessibility (SA)	SA1	0.898	3.305
	SA2	0.942	1.986
	SA3	0.895	3.294
	SA4	0.793	2.227
	SA5	0.949	2.498
Student educational mobility (SM)	SM1	0.813	2.015
	SM2	0.876	2.749
	SM3	0.825	2.152
	SM4	0.871	2.826
	SM5	0.775	2.080

Note. AREF = availability of regional educational facilities; ESC = educational spatial connectivity; IES = educational service integration; SA = school accessibility; SM = student educational mobility.

Table 3.
Reliability and convergent validity

Construct	**Cronbach's alpha**	**Composite reliability (rho_a)**	**Composite reliability (rho_c)**	**AVE**
AREF	0.911	0.926	0.933	0.736
ESC	0.856	0.857	0.897	0.635
IES	0.915	0.919	0.936	0.746
SA	0.939	0.951	0.953	0.804
SM	0.890	0.898	0.919	0.694

Table 4.
Discriminant validity (HTMT ratios)

	AREF	**ESC**	**IES**	**SA**
ESC	0.602			
IES	0.487	0.592		
SA	0.283	0.632	0.453	
SM	0.217	0.559	0.319	0.415

Regarding CMB, Harman's single-factor test indicates that a single unrotated factor accounts for 34.7% of the total variance, below the 50% threshold, and all inner VIF values in the full collinearity assessment are below 3.3.[23] Taken together with the results described in the Method section, these results suggest that CMB is unlikely to be a serious concern. However, shared method variance cannot be ruled out entirely in a single-source design.

[23] N Kock, "Common Method Bias in PLS-SEM: A Full Collinearity Assessment Approach," *International Journal of E-Collaboration* 11, no. 4 (2015): 1–10, https://doi.org/10.4018/ijec.2015100101.

Structural Model

The model explains 58.2% of the variance in educational spatial connectivity (R^2 = 0.582, adjusted R^2 = 0.574) and 30.9% of the variance in educational service integration (R^2 = 0.309, adjusted R^2 = 0.298) (Table 5). Effect sizes for the direct paths to spatial connectivity range from $f^2 = 0.046$ (service integration) to $f^2 = 0.215$ (facility availability), with student mobility at $f^2 = 0.134$. Across all structural paths, the smallest effect is f^2 = 0.013 (mobility to service integration), consistent with the nonsignificant H7. By Cohen's (1988) conventions, all effects are small to moderate, and none reach the large threshold (0.35).

Predictive relevance at the model level, computed as $Q^2 = 1 - (1 - R^2ESC)(1 - R^2IES) = 1 - (1 - 0.582)(1 - 0.309) = 0.711$, indicates that the exogenous constructs jointly account for a substantial share of the variance in the two endogenous constructs.

Table 5.
Coefficients of determination

Endogenous construct	R^2	Adjusted R^2
Educational spatial connectivity	0.582	0.574
Educational service integration	0.309	0.298

Table 6 reports the bootstrapped path coefficients. Eight of the ten hypotheses are supported. School accessibility (β = 0.309, t = 5.857), facility availability (β = 0.339, t = 6.758), student mobility (β = 0.260, t = 5.370; all $p < 0.001$), and service integration (β = 0.167, t = 2.966, p = 0.003) are positively associated with spatial connectivity, supporting H1 to H4. Accessibility (β = 0.286, t = 4.548, $p < 0.001$) and facility availability (β = 0.349, t = 5.541, $p < 0.001$) predict service integration, supporting H5 and H6, whereas mobility does not (β = 0.105, t = 1.577, p = 0.115), so H7 is rejected.

Table 6.
Hypothesis testing (bootstrapping, 5,000 resamples)

Hypothesis	Path	β (O)	Mean (M)	SD	t	p	Decision
H1	SA → ESC	0.309	0.308	0.053	5.857	< 0.001	Supported
H2	AREF → ESC	0.339	0.338	0.050	6.758	< 0.001	Supported
H3	SM → ESC	0.260	0.262	0.048	5.370	< 0.001	Supported
H4	IES → ESC	0.167	0.167	0.056	2.966	0.003	Supported
H5	SA → IES	0.286	0.283	0.063	4.548	< 0.001	Supported
H6	AREF → IES	0.349	0.350	0.063	5.541	< 0.001	Supported
H7	SM → IES	0.105	0.108	0.067	1.577	0.115	Not supported
H8	SA → IES → ESC	0.048	0.048	0.021	2.290	0.022	Supported

H9	AREF → IES → ESC	0.058	0.058	0.023	2.564	0.010	Supported
H10	SM → IES → ESC	0.018	0.018	0.014	1.297	0.195	Not supported

The mediation tests show a selective pattern. Service integration transmits part of the effect of accessibility (indirect β = 0.048, p = 0.022) and of facility availability (indirect β = 0.058, p = 0.010) on spatial connectivity. Because the corresponding direct effects remain significant, both cases represent complementary partial mediation;[24] The indirect paths account for about 13% of the total effect of accessibility (0.048/0.357) and 15% of the total effect of facility availability (0.058/0.397). The indirect path from mobility is not significant (β = 0.018, p = 0.195), so H10 is rejected: mobility relates to connectivity directly, but not through the integration mechanism.

Discussion

A District-Differentiated Coverage Gap

The spatial analysis shows that access to state upper-secondary education in Malang City is territorially uneven, consistent with work placing facility distribution at the center of educational equity.[25] Proportional and absolute measures identify different priority districts. Sukun's 52.40% coverage gap means a large share of residents lack a nearby public school, while Kedungkandang's 1,242.13 ha gap affects many residents in aggregate, even though the proportion is lower. Interventions keyed to only one measure would miss part of the problem. Coverage maps establish territorial context but do not, by themselves, demonstrate deprivation; some unserved areas may have low residential density, a private-school supply, or compensating public transport. The structural model addresses the experiential side of this question, but a full test would require linking household locations to coverage polygons, a step outside the present design.

Direct Effects on Perceived Connectivity

Within the sample, perceived facility availability has the largest standardized effect on perceived connectivity (β = 0.339), followed by accessibility (β = 0.309) and mobility (β = 0.260). The model explains 58.2% of the variance. The ordering is consistent with

[24] Hair et al., *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*.
[25] Cobb, "Geospatial Analysis: A New Window into Educational Equity, Access, and Opportunity"; Han et al., "Improving Educational Equity by Maximizing Service Coverage in Rural Changyuan, China: An Evaluation-Optimization-Validation Framework Based on Spatial Accessibility to Schools"; Rueda, Moura, and Cantillo, "Quality of Schools and Inequalities in Access: A Socio-Territorial Analysis."

accessibility theory, van Wee,[26] and with spatial studies that treat facility distribution and physical access as primary determinants of educational reach.[27] Facility availability outweighs accessibility in students' perceptions: the presence and adequacy of schools matter more for feeling connected than ease of travel alone. Proximity to a poorly equipped school does not amount to meaningful access.

Three qualifications bound this interpretation. First, predictors and the outcome are self-reported by the same respondents, so part of the shared variance may reflect consistency in perception rather than structural relationships; the CMB checks limit, but do not eliminate, this concern. Second, no effect reaches Cohen's large threshold, and the highest path coefficient is 0.339, so the constructs should be described as meaningful correlates rather than dominant drivers. Third, the modest direct effect of service integration ($\beta = 0.167$, $f^2 = 0.046$) suggests that integration operates as a supporting mechanism rather than a primary determinant in students' perceptions.

Reading the survey results against the coverage map raises a further possibility. Perceived accessibility carries less weight than perceived availability of facilities, even though Sukun, Blimbing, and Kedungkandang show large coverage gaps. Students in poorly served districts may have adapted their expectations of what counts as accessible, or may rely on long commutes and private transport, which can blunt the perceived salience of distance. This is speculative; testing it requires geocoded respondents and a served-versus-unserved multigroup analysis, which we identify as the priority next step.

Why Mediation Is Selective

Service integration mediates the effects of accessibility and facility availability but not of mobility. Two readings are plausible.

The institutional reading starts from the observation that accessibility and facility provision are, at root, institutional variables: schools are sited by government decision, public agencies plan road networks, and facilities are financed through public budgets. Where these inputs are present, coordination mechanisms such as aligned admission zoning, shared support services, and joint education-transport planning become both feasible and consequential. Facilities supply the material infrastructure through which

[26] van Wee, "Accessibility and Equity: A Conceptual Framework and Research Agenda."
[27] Cobb, "Geospatial Analysis: A New Window into Educational Equity, Access, and Opportunity"; Han et al., "Improving Educational Equity by Maximizing Service Coverage in Rural Changyuan, China: An Evaluation-Optimization-Validation Framework Based on Spatial Accessibility to Schools."

integrated services are delivered; accessibility supplies the routes along which those services are reached. Integration then works as a system-level amplifier of institutional inputs. Mobility, by contrast, is largely an individual or household response to institutional gaps: students commute across districts precisely because their own district is underserved, and this movement reflects the absence of integration rather than its presence. A significant direct effect of mobility with no indirect effect fits this account. It is consistent with the mobility-constraint literature, which treats individual movement as shaped by structural conditions rather than as an independent driver of system outcomes,[28] and with network-based views that locate integration in relations between institutions rather than in the movement of individuals.[29]

A measurement reading cannot be excluded. The mobility construct captures self-reported movement between educational locations. If respondents interpreted this narrowly, as routine commuting to a single school rather than engagement with multiple services across districts, the construct may not tap the kind of mobility that could plausibly feed integration. A student who travels 45 minutes to the same school every day is mobile without ever encountering coordinated multi-service provision. Future instruments should distinguish routine commuting from cross-district use of extracurricular, remedial, or supplementary services.

The practical implication is the same under either reading, and it is testable. Mobility support alone, such as bus subsidies or route expansion, is unlikely to produce a more integrated education system unless institutional coordination is strengthened alongside it. Expanding coverage and facilities, by contrast, can work through both the direct and indirect pathways.

Reading the Two Analyses Together

The GIS and PLS-SEM strands describe two layers of the same problem: the territorial distribution of SMAN services, and how students experience that distribution. Read jointly, they support one substantive claim. Spatial equity in Malang City depends on the interaction of where schools are located (a territorial question), how well they are equipped (an institutional question), and how well they are coordinated with supporting services (an integrative question). Interventions addressing a single dimension, such as

---

[28] Banister, *Transport and Mobility Transitions*; Cagney et al., "Urban Mobility and Activity Space."
[29] Scott, *Social Network Analysis*.

adding schools without coordinating admission zoning, or improving transport without strengthening facilities, are unlikely to suffice. This layered account aligns with recent arguments that educational geography should move beyond distance-based measures toward a more relational, institutional understanding of educational reach.[30]

The two layers are not linked at the individual level in the present design, so any inference that combines them, for example, that students in Kedungkandang's unserved zone perceive lower connectivity than students in Klojen, is suggestive rather than demonstrated.

Theoretical and Practical Implications

Theoretically, the study adds two points. For accessibility theory, perceived accessibility and perceived connectivity are related but distinct, and their relationship is partly mediated by service integration; proximity should not be treated as a sufficient proxy for educational reach. For spatial interaction theory, individual movement and institutional coordination are analytically distinct mechanisms with different consequences for system-level outcomes; collapsing them under a single connectivity label obscures how education systems respond to intervention.

Practically, and within the limits of a purposive sample of 200 students, the findings suggest three points: policy discussion of educational equity in Malang City should be district-differentiated; expanding facility provision may yield larger perceived benefits than expanding physical access alone; and mobility support will not generate integration benefits without accompanying institutional coordination. These are hypotheses for stronger designs to test, not directives derived from the present evidence.

Conclusion

This study combined a GIS service-area analysis with PLS-SEM in a sequential design to examine the spatial equity of SMAN services in Malang City. Two findings anchor the argument. About one third of the city area lies beyond the 3,000 m network service area of a *senior high school*, with gaps concentrated in Sukun (the highest proportion), Kedungkandang (the largest absolute area), and Blimbing, while Klojen is fully covered. Therefore, educational equity policy in the city needs to be differentiated by district. Within the sample, perceived accessibility, facility availability, and mobility

[30] Guo and Li, "Regional Inequality in China's Educational Development: An Urban-Rural Comparison"; Timpabi et al., "School Accessibility Assessment for Walking and Cycling; the Role of Street Connectivity and Land Use Variables."

are all positively associated with perceived spatial connectivity. Service integration partially mediates the associations between the first two and perceived spatial connectivity, but not between mobility and perceived spatial connectivity. This pattern is consistent with the view that institutional inputs work through institutional coordination, while individual mobility does not automatically translate into system-level integration.

Four limitations qualify these results. The purposive sample cannot represent all SMAN students in Malang City. All constructs are self-reported, so shared method variance cannot be entirely ruled out despite procedural and statistical checks. The two analytical strands were not linked at the individual level: respondents were not geocoded to coverage polygons, and no served-versus-unserved comparison was run. The cross-sectional design does not capture change in school siting, road development, or population growth.

Future work should combine probability-based, district-stratified sampling with geocoded respondent data, test for served-versus-unserved differences using multigroup analysis, and use location-allocation modeling to evaluate alternative school placements. If the associations identified here reflect real institutional dynamics, interventions in Malang City would need to pair three elements: expanding SMAN coverage where the unserved area is largest (Sukun and Kedungkandang), improving network connectivity to existing schools in peripheral areas (Blimbing), and coordinating school planning with admission zoning and transport services. These are the priorities the present evidence points toward, and stronger designs should test them.

Bibliography

Agency, National Standardization. “SNI 03-1733-2004: Guidelines for the Planning of Urban Residential Environments.” National Standardization Agency, 2004.

Agostinelli, F, M Luflade, and P Martellini. “On the Spatial Determinants of Educational Access.” NBER Working Paper No. 32246. National Bureau of Economic Research, 2024. https://doi.org/10.3386/w32246.

Álvarez-Rivadulla, M. J., A. M. Jaramillo, F. Fajardo, L. Cely, A. Molano y F. Montes. “College Integration and Social Class.” *Higher Education* 84, no. 3 (2022): 647–69. https://doi.org/10.1007/s10734-021-00793-6.

Assefa, E A. “Infrastructure Matters: How School Facilities Influence Quality Education.” *The Journal of Quality in Education* 16, no. 27 (2026): 73–95. https://doi.org/10.37870/joqie.v16i27.520.

Banister, D. *Transport and Mobility Transitions*. Edward Elgar Publishing, 2021.

Bank, World. “World Development Report 2021: Data for Better Lives.” World Bank, 2021.

Bhatt, P, A Kumar, R Choudhary, A Dahiya, and S Raj. “The Role of Educational Facilities and Community Engagement in Achieving SDG 4: A Structural Model Evaluation of Northern India Educational System.” *Sage Open* 16, no. 1 (2026). https://doi.org/10.1177/21582440261416745.

Cagney, K. A., E York Cornwell, A. W. Goldman, and L Cai. “Urban Mobility and Activity Space.” *Annual Review of Sociology* 46, no. 1 (2020): 623–48. https://doi.org/10.1146/annurev-soc-121919-054848.

Cobb, C D. “Geospatial Analysis: A New Window into Educational Equity, Access, and Opportunity.” *Review of Research in Education* 44, no. 1 (2020): 97–129. https://doi.org/10.3102/0091732X20907362.

Cohen, Jacob. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates, 1988.

Custers, G, M Das, and G Engbersen. “Change or Stability in Educational Inequalities? Educational Mobility and School Effects in the Context of a Major Urban Policy.” *Urban Studies* 60, no. 14 (2023): 2852–73. https://doi.org/10.1177/00420980231162774.

Guo, Y, and X Li. “Regional Inequality in China’s Educational Development: An Urban-Rural Comparison.” *Heliyon* 10, no. 4 (2024): e26249. https://doi.org/10.1016/j.heliyon.2024.e26249.

Hair, J F, G.T. M. Hult, C. M. Ringle, and M Sarstedt. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 3rd ed. Sage, 2022.

Han, Z., C. Cui, Y. Kong, Q. Li, Y. Chen, and X. Chen. “Improving Educational Equity by Maximizing Service Coverage in Rural Changyuan, China: An Evaluation-Optimization-Validation Framework Based on Spatial Accessibility to Schools.” *Applied Geography* 152 (2023): 102891. https://doi.org/10.1016/j.apgeog.2023.102891.

Henseler, J, C. M. Ringle, and M Sarstedt. "A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling." *Journal of the Academy of Marketing Science* 43, no. 1 (2015): 115–35. https://doi.org/10.1007/s11747-014-8403-9.

Kock, N. "Common Method Bias in PLS-SEM: A Full Collinearity Assessment Approach." *International Journal of E-Collaboration* 11, no. 4 (2015): 1–10. https://doi.org/10.4018/ijec.2015100101.

Kock, N, and P Hadaya. "Minimum Sample Size Estimation in PLS-SEM: The Inverse Square Root and Gamma-Exponential Methods." *Information Systems Journal* 28, no. 1 (2018): 227–61. https://doi.org/10.1111/isj.12131.

OECD. "Education Policy Outlook 2023." OECD Publishing, 2023.

Rueda, J., F. Moura y V. Cantillo. "Quality of Schools and Inequalities in Access: A Socio-Territorial Analysis." *Applied Geography* 188 (2026): 103909. https://doi.org/10.1016/j.apgeog.2026.103909.

Sánchez, M., E. Expósito y J. Aguilar. "Industry 4.0: Survey from a System Integration Perspective." *International Journal of Computer Integrated Manufacturing* 33, no. 10–11 (2020): 1017–41. https://doi.org/10.1080/0951192X.2020.1775295.

Scandurra, R, A Zancajo, and X Bonal. "Opting out of Neighborhood Schools: The Role of Local Education Markets in Student Mobility." *Population, Space and Place* 28, no. 5 (2022): e2542. https://doi.org/10.1002/psp.2542.

Scott, J. *Social Network Analysis*. 4th ed. Sage, 2020. https://doi.org/10.4135/9781529716597.

Sharma, G., and G. R. Patil. "Spatial and Social Inequities for Educational Services Accessibility: A Case Study for Schools in Greater Mumbai." *Cities* 122 (2022): 103543. https://doi.org/10.1016/j.cities.2021.103543.

Timpabi, A. P., G Dumedah, C. A. Adams, J Quaye-Ballard, and K. K. Osei. "School Accessibility Assessment for Walking and Cycling: The Role of Street Connectivity and Land Use Variables." *Urban, Planning and Transport Research* 12, no. 1 (2024). https://doi.org/10.1080/21650020.2024.2312170.

UNESCO. "Global Education Monitoring Report 2022." UNESCO Publishing, 2022.

Wee, B. van. "Accessibility and Equity: A Conceptual Framework and Research Agenda." *Journal of Transport Geography* 104 (2022): 103421. https://doi.org/10.1016/j.jtrangeo.2022.103421.

Xie, Y, and M Zhang. "Synergy of Higher Education Resources and Digital Infrastructure Construction in China: Regional Differences, Dynamic Evolution and Trend Forecasting." *PLOS ONE* 19, no. 6 (2024): e0304613. https://doi.org/10.1371/journal.pone.0304613.

Zhang, X, E S Lim, and M Chen. "Promoting Sustainable Urban Mobility: Factors Influencing e-Bike Adoption in Henan Province, China." *Sustainability* 16, no. 22 (2024): 10136. https://doi.org/10.3390/su162210136.