



Examining the Correlation Between Motorway Infrastructure and District-Level Literacy Rates: A Case Study of Punjab

Awais Akmal¹, Shabir Hussain² & Minhaj Fatima³

¹MPhil Scholar, University of Sargodha, Email: awaisakmal80@gmail.com

²Area study centre Russia China & Central Asia. University of Peshawar, Email: malikshabirawan@gmail.com

³MPhil Scholar, University of Sargodha, Email: Mrsdania12101@gmail.com

ARTICLE INFO

Article History:

Received:	June	14, 2025
Revised:	July	27, 2025
Accepted:	August	18, 2025
Available Online:	August	30, 2025

Keywords:

Motorway development, literacy rate, Punjab, regional disparity, public policy

Corresponding Author:

Awais Akmal

Email:

awaisakmal80@gmail.com

ABSTRACT

This study uses district-level data and geographic analysis to investigate the relationship between road infrastructure and literacy outcomes in Punjab, Pakistan. Districts with better motorway access, such as Lahore, Rawalpindi, and Gujrat, have significantly higher literacy rates than remote, unconnected districts, such as Rajanpur and Muzaffargarh, according to a study that links literacy rates to national motorways (M-1 to M-5 and CPEC routes). The study uses both quantitative and qualitative methods to identify key factors that link highway connectivity to human capital development, including improved institutional access, educational mobility, and private sector involvement. To reduce regional inequalities and encourage inclusive literacy development, it concludes by promoting transport policies that are integrated with educational planning.



Introduction

Both economic and policy research have long focused on the importance of infrastructure for national development. In the past, transport networks – particularly highways and motorways – have acted as catalysts for labor mobility, regional integration, and access to services, all of which have contributed to socioeconomic transformation. The motorway system is one of Pakistan's most ambitious infrastructure projects since the country's independence. The cornerstone of trade, transit, and strategic connectivity under the China-Pakistan Economic Corridor (CPEC) is the M-2 motorway, first built in 1997 to connect Lahore and Islamabad. Since then, the motorway network

has become a comprehensive national grid that runs from Peshawar to Karachi and from Gwadar to Kashgar.¹

The epicenter of this development model has been the province of Punjab, home to over 110 million people and accounting for more than half of Pakistan's GDP.² Punjab, due to its relatively large budget capacity and administrative efficiency, has invested significantly in highway infrastructure, including the M-3 (Lahore-Multan), M-4 (Faisalabad-Multan), and M-5 (Multan-Sukkur) motorways. These developments have improved the flow of goods, significantly reduced travel times, and increased access to essential services such as education.³ However, while the economic benefits of these corridors have been well-studied, little is known about their social impacts, particularly in terms of human capital development such as literacy.

Although conceptually clear, the link between education and transport infrastructure has not received sufficient empirical attention. Improved road connectivity makes it easier for students to physically visit schools and colleges, provides greater mobility for teachers and administrative staff, and makes it easier for educational goods and private investment to enter the market.⁴ Studies conducted in developing countries have demonstrated that access to paved roads and affordable transit has a positive impact on school attendance and literacy rates.⁵ Important questions about infrastructure-driven inequalities in educational outcomes arise from the fact that districts in Punjab with high motorway access, such as Lahore, Rawalpindi, Gujrat, and Faisalabad, consistently have higher literacy rates than districts with low connectivity, such as Rajanpur, Muzaffargarh, and Dera Ghazi Khan.⁶

The inequality of development is further complicated by Punjab's high level of education system, both along gender and urban-rural lines. In addition to being trade routes, motorways are also symbols of modernity and mobility, providing families with easy access to cities, universities, and tuition centers. By expanding opportunities and changing the regional human capital landscape, motorways essentially serve as educational corridors. But without comprehensive design, this expansion can exacerbate pre-existing inequalities, making infrastructure a double-edged sword that can either elevate or depress, depending on regional access.⁷

This study therefore positions itself at the nexus of education policy and infrastructure development. It examines whether freeway access affects literacy outcomes in districts of Punjab in order to add a new perspective to the discussion about educational equity and development planning in Pakistan.

Pakistan has made great progress in infrastructure, but educational disparities still exist at the regional and district levels, especially in literacy. According to the latest data released by the Pakistan Bureau of Statistics, literacy rates in the most administratively developed province of

¹ Government of Pakistan. (2021). *National Transport Policy of Pakistan 2018–2030* (p. 18).

² Punjab Bureau of Statistics. (2022). *Punjab Development Statistics 2022* (p. 12).

³ National Highway Authority. (2023). *Motorway Projects Under CPEC and PSDP* (pp. 6–8).

⁴ Banerjee, A., Duflo, E., & Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in China. *National Bureau of Economic Research Working Paper No. 17897*, p. 4.

⁵ Porter, G. (2014). Transport services and their impact on poverty and growth in rural sub-Saharan Africa: A review of recent research and future research needs. *Transport Reviews*, 34(1), p. 27.

⁶ Pakistan Bureau of Statistics. (2024). *Punjab District Wise Literacy Rates* [Infographic Dataset].

⁷ Ahmed, V., & O'Donoghue, C. (2010). Global economic crisis and poverty in Pakistan. *International Journal of Microsimulation*, 3(1), p. 142.

Punjab vary widely, from 84.8 percent in Murree to just 36.1 percent in Rajanpur.⁸ Despite national policy initiatives such as the Punjab Education Sector Plan 2019-2024, which prioritizes universal access and quality improvement in education, these figures reflect regional disparities in educational attainment.⁹

While socioeconomic factors such as income, gender, and urbanization are often acknowledged to influence literacy, less is known about the spatial importance of infrastructure, particularly the presence or lack of motorway connectivity. Notably, major highways such as the M-1, M-2, and M-4 immediately connect many districts, including Lahore, Gujrat, Rawalpindi, and Jhelum. These highways have greatly reduced the time it takes to get to educational institutions, increased accessibility for both professors and students, and encouraged private sector investment in education.¹⁰ On the other hand, southern districts that are either on the outskirts of development corridors or lack direct motorway connectivity, such as Dera Ghazi Khan, Muzaffargarh, and Rajanpur, consistently lag behind in literacy.

This spatial distribution raises an important question: Is Punjab's infrastructure, particularly the construction of motorways, an important but underappreciated factor in determining educational attainment? Despite the growing academic interest in the role of infrastructure in economic development,¹¹ few empirical studies have looked at the direct relationship between infrastructure and metrics of social development such as literacy. Because of this, existing models of education policy may not consider how roads and highways facilitate physical access to school. The potential for strategic planning that links infrastructure investment with human capital development is limited by this omission.

Additionally, a new wave of infrastructure development has emerged through the China-Pakistan Economic Corridor (CPEC), which includes the construction of several motorways and expressways across Punjab.¹² While the economic goals of these initiatives are clearly stated, their social impact is difficult to assess, especially when it comes to improved access to education. Infrastructure is spending risks exacerbating rather than reducing existing spatial disparities if this relationship is not scientifically assessed.

Thus, by examining the potential causal relationship between Punjabi district-level literacy and motorway expansion, this study fills a major gap in the literature. In doing so, it advances a more comprehensive understanding of the dual nature of infrastructure, which, depending on how equitably distributed and accessible it is, can both connect and isolate.

The main objective of this study is to investigate the empirical relationship between literacy outcomes and motorway infrastructure in Punjab, Pakistan at the district level. Although most people agree that infrastructure development accelerates economic growth, regional planning frameworks have largely ignored its impact on social indicators, especially education. This study aims to bridge this gap by examining the impact of Punjab's road network expansion on literacy rates and educational access across different geographical areas.

⁸ Pakistan Bureau of Statistics. (2024). *Punjab District Wise Literacy Rates* [Infographic Dataset].

⁹ Government of Punjab. (2019). *Punjab Education Sector Plan 2019–2024* (p. 7).

¹⁰ Jamil, B. R. (2019). Education reforms in Punjab: Moving from access to quality. *Idara-e-Taleem-o-Aagahi Policy Paper Series*, 3(2), p. 4.

¹¹ Estache, A., & Fay, M. (2010). Current debates on infrastructure policy. *World Bank Policy Research Working Paper*, No. 4410, p. 12.

¹² Ministry of Planning, Development & Special Initiatives. (2023). *CPEC Projects Summary Report* (pp. 18–20).

The specific objective of this study is to determine whether, the presence of road infrastructure and literacy levels are statistically correlated across 40 districts of the province. It investigates the gap in educational performance between rural or unconnected districts such as Rajanpur, Dera Ghazi Khan, and Muzaffargarh and motorway-connected districts such as Lahore, Rawalpindi, Gujrat, and Faisalabad, using comparative analysis and spatial mapping.

In addition to quantifying this association, this study aims to explore plausible causal pathways through which motorway development may affect literacy. Improved physical access to schools and colleges, shorter commutes for teachers and students, higher attendance rates, and greater opportunities for private involvement in the education sector are some of these pathways. Motorways are thought to facilitate educational mobility and allow for the redistribution of educational resources to semi-urban and rural locations.

The study also examines whether complementary investments in infrastructure projects, as well as educational staff, facilities, and policy measures, have been made in Punjab. In doing so, it seeks to determine whether the increase in literacy in areas with motorways is a direct result of improved connectivity or the result of broader institutional reforms. This assessment is essential to determine whether infrastructure promotes equitable development or perpetuates existing regional disparities.

Finally, this study aims to provide policy recommendations for integrating strategies for educational development with infrastructure planning. The findings of this study contribute to reframing Pakistan's infrastructure policy in the context of sustainable and equitable human development, as roads and highways have the potential to facilitate both economic and social transformation. Aligned with the United Nations Sustainable Development Goals, particularly SDG 4 (quality education) and SDG 9 (industry, innovation, and infrastructure), this study emphasizes the need for multi-sectoral collaboration to ensure that infrastructure projects deliver both educational returns and economic returns.¹³

The main question of this study is: Does the road infrastructure of Punjab, Pakistan have a major impact on district-level literacy rates? Although the economic impact of road networks has been studied previously, empirical policy research has not yet examined how these networks affect human development metrics, particularly schooling. By developing a series of coherent research questions that guide the study's theoretical framework and methodological design, the current study aims to bridge this knowledge gap.

The first and foremost inquiry considers whether there is a statistically significant relationship between Punjab's literacy rate and motorway connectivity. The inquiry aims to find out whether districts that have direct access to motorways have higher literacy rates than districts that do not. This relationship needs to be established in order to reposition infrastructure as a driver of educational development and as a tool for economic integration.¹⁴

The second inquiry investigates the relationship between road development and the spatial distribution of literacy. It involves detecting differences in literacy performance across districts and contrasting trends between locations connected to motorways and those that are not. The aim of

¹³ Banerjee, A., Duflo, E., & Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in China. *National Bureau of Economic Research Working Paper No. 17897*, p. 21: United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development* (pp. 14–17).

¹⁴ Estache, A., & Fay, M. (2007). Current debates on infrastructure policy. *World Bank Policy Research Working Paper*, No. 4410, p. 13.

this study is to determine whether geography—specifically, proximity to major transport corridors—affects school attendance, resource allocation, and access to educational opportunities. This inquiry is particularly relevant to areas of southern Punjab where literacy rates continue to be low despite progress at the provincial level.¹⁵

Exploring the effective pathways through which road infrastructure can influence educational achievement is the subject of a third research investigation. These strategies could include shorter commutes, higher student enrollment, better access to teachers, more funding from the private sector, and greater administrative control. This study aims to investigate the structural channels that facilitate or hinder educational progress in areas with abundant infrastructure by looking at these pathways to go beyond the correlation.¹⁶

Finally, the study raises a normative question: Is it possible to address educational disparities in Punjab through the strategic use of infrastructure development? If so, how can planning frameworks support equitable production of human capital by better integrating education sector reforms with transport policy? In light of the Sustainable Development Goals (SDGs), particularly SDGs 4 and 9, this question is forward-looking and seeks to influence policy debates on inclusive planning, inter-district equity, and sustainable development.¹⁷

By placing the analysis within a larger development narrative that sees roads as important tools for social change rather than simply means of trade, these research questions collectively seek to disentangle the complex relationships between infrastructure and literacy.

The main premise of this study is that physical infrastructure, particularly motorway connections, facilitates educational outcomes and accessibility. The study presents the following key, testable hypotheses, supported by preliminary empirical research on the socio-economic impacts of transit corridors and local development: Districts in Punjab that have direct access to national motorway infrastructure have significantly higher literacy rates than districts that lack such connectivity.

This hypothesis is intended to be quantitatively tested through correlation analysis and geographical comparison of literacy rates and the distribution of motorways across districts of Punjab. It is expected that improved physical access to educational facilities, made possible by roads, will increase student enrollment, reduce dropout rates, increase teacher availability, and boost funding for the education sector.¹⁸

This study is of great value both in academic debates and in evidence-based public policy formulation. Although the impact of infrastructure on human development, particularly education, has received relatively little attention in the field of development studies, it is often examined through the prism of economic rewards, such as business efficiency, industrial growth, or real estate expansion. By examining whether Pakistan's growing road infrastructure also generates significant social benefits, particularly in terms of increasing literacy rates at the district level in Punjab, this study challenges such rigid frameworks.

¹⁵ Punjab Bureau of Statistics. (2022). *Punjab Development Statistics 2022* (p. 129).

¹⁶ Porter, G. (2014). Transport services and their impact on poverty and growth in rural sub-Saharan Africa: A review of recent research and future research needs. *Transport Reviews*, 34(1), p. 30.

¹⁷ United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development* (pp. 15–17).

¹⁸ Banerjee, A., Duflo, E., & Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in China. *National Bureau of Economic Research Working Paper No. 17897*, p. 3.

The study's emphasis on literacy, a core aspect of human capital, advances a more comprehensive understanding of infrastructure-led development. It tests the idea that road networks support long-term socio-economic mobility, gender inclusion, educational access, and market connectivity. This approach places infrastructure research within the broader framework of equitable development and expands its theoretical boundaries.¹⁹

Pakistan's ongoing infrastructure investment under the China-Pakistan Economic Corridor (CPEC) and the National Programme make this study particularly relevant from a policy perspective. Billions of rupees are being spent on road construction and motorway expansion, yet policy frameworks rarely take into account how these projects affect access to essential public services such as health and education. This study encourages policymakers to link transport investments with education reforms by providing empirical evidence on the spatial distribution of literacy outcomes in relation to highway development. This information can be used to inform multi-sectoral planning.²⁰

Furthermore, the study is useful in addressing regional disparities. Despite being somewhat developed in terms of infrastructure and administration, Punjab nevertheless has significant inter-provincial disparities. With excellent access to the M-1, M-2, and M-4 highways, northern and central districts routinely outperform southern districts in literacy metrics. This discrepancy means that in the absence of comprehensive spatial planning, infrastructure may worsen regional disparities rather than address them. Therefore, the study makes a compelling case for integrated development, which aligns infrastructure design with educational investment, especially in underserved districts.²¹

Finally, this study is in line with the framework of global development, particularly the United Nations Sustainable Development Goals (SDGs). SDG 9 (Industry, Innovation, and Infrastructure) and SDG 4 (Quality Education) are directly impacted by it as it highlights the importance of inclusive infrastructure that supports human capital development. This study provides an important body of evidence for future interventions in infrastructure-led development planning by empirically illustrating the relationship between physical connectivity and educational equity.²²

This article is organized into six complete sections, each of which adds to the logical progression of the study's core contention, which is that the road infrastructure of Punjab, Pakistan significantly affects literacy outcomes.

Background information, problem statement, objectives and hypothesis, and explanation of the significance of the study are all included in the first section, which also introduces the research. It also outlines the main research questions that serve as the compass of the investigation.

A comprehensive analysis of the body of research on the relationship between infrastructure and human development is provided in the second section. It identifies theoretical gaps, highlights local and international research on road development and educational access, and places the current study within a multidisciplinary academic framework.

¹⁹ Estache, A., & Fay, M. (2007). Current debates on infrastructure policy. *World Bank Policy Research Working Paper*, No. 4410, p. 12.

²⁰ Ministry of Planning, Development & Special Initiatives. (2023). *CPEC Projects Summary Report* (p. 19).

²¹ Punjab Bureau of Statistics. (2022). *Punjab Development Statistics 2022* (pp. 129–131).

²² United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development* (pp. 15–17).

The research methodology, including variables, data sources, sampling criteria, and analytical tools used, is described in the third section. It describes the rationale behind the motorway connectivity classification, literacy measurement, and district selection. The mixed methods approach, which combines thematic and spatial interpretation with quantitative data analysis, is also covered in this section.

The empirical results are presented in the fourth section. It provides correlation results, geographical maps, and statistical comparisons that show how motorway infrastructure and literacy rates at the district level are related. Where appropriate, this section also presents data that is broken down by gender and urban/rural division.

A discussion of the findings in light of the research topics and a more general theoretical framework is provided in Section 5. It analyzes the findings, discusses the reasons, and examines whether motorway access increases or decreases educational inequality. Furthermore, it contrasts the findings with case studies from both domestic and foreign locations.

The research concludes in the final section, which also presents policy recommendations and a summary of key findings. It highlights the need for integrated development plans that integrate investment in education with infrastructure planning, especially in underdeveloped areas. Directions for future research in this area are also suggested, such as multi-provincial comparisons and longitudinal studies.

This paper presents a thorough and fact-based examination of the relationship between literacy and transportation infrastructure through this methodology, adding new information to the debate in public policy and development studies.

Literature Review

In the mainstream literature on development, the relationship between infrastructure development and educational outcomes is relatively sparse. While much scholarly work has been done to examine how roads, highways, and transportation systems affect economic indicators such as trade, employment, and industrial production, little is known about how they affect social sectors such as education, especially in developing countries.²³ By critically analyzing previous international and local research that examines the relationship between infrastructure, especially transport networks, and literacy and other human capital outcomes, this literature review seeks to bridge this conceptual gap.

There is growing international agreement that transport infrastructure is essential to making education more accessible. According to a study by Banerjee, Duflo, and Qian (2012) that examined China's highway system, areas with better road connectivity experienced higher school enrollment and educational investment, due to lower travel costs and greater availability of teachers.²⁴ Similarly, Gannon and Liu (1997) claim that rural transport services have a direct impact on human development by removing physical barriers to access to health and educational facilities.²⁵ Porter's (2014) research on sub-Saharan Africa supports these findings and shows that

²³ Estache, A., & Fay, M. (2007). Current debates on infrastructure policy. *World Bank Policy Research Working Paper*, No. 4410, p. 2.

²⁴ Banerjee, A., Duflo, E., & Qian, N. (2012). On the road: Access to transportation infrastructure and economic growth in China. *National Bureau of Economic Research Working Paper* No. 17897, pp. 3–5.

²⁵ Gannon, C., & Liu, Z. (1997). Poverty and transport. *World Bank Transport Paper Series*, TWU-30, p. 11.

paved roads reduce the cost of time for students, especially girls, leading to increased literacy and lower dropout rates.²⁶

Although still poorly studied, the relationship between infrastructure and education has received some attention in South Asia. When Khandkar et al. (2009) looked at rural road programs in Bangladesh; they found that communities that had improved roads saw statistically significant increases in school attendance and literacy rates.²⁷ These improvements were more pronounced in previously disadvantaged communities, suggesting that infrastructure can act as an equalizer if strategically placed. However, the report warns that the benefits of increased access will not be realized in the absence of additional spending on the education system, such as classroom infrastructure, teacher training, and curriculum revision.²⁸

Research on the relationship between education and infrastructure development in Pakistan is still scattered and largely anecdotal. Government and donor-led assessments often pay little attention to social impacts in favor of outcomes such as kilometers of roads built. Some local studies have attempted to investigate these processes. For example, although the analysis is not disaggregated by literacy or local connectivity, Ahmed and O'Donoghue (2010) show how improvements in school enrollment and access to basic services were also observed in areas with improved road connectivity under Pakistan's Public Sector Development Program (PSDP).²⁹ Similarly, Jamil (2019) discusses how transit corridors have helped make schools more accessible in urban Punjab, but they also point out that rural districts still face infrastructure deprivation, resulting in unequal literacy outcomes.³⁰

The expansion of Pakistan's motorway network, particularly as part of the China-Pakistan Economic Corridor (CPEC), presents a new experimental frontier. The potential of CPEC to impact human development metrics has received little attention, despite the fact that its macroeconomic impacts on trade, employment and foreign direct investment have been extensively researched. Publications by the Ministry of Planning, Development and Special Initiatives and the Planning Commission emphasize industrial parks, transport corridors and economic zones, but they hardly address the consequences of social spillovers such as access to health or education.³¹

From a conceptual perspective, the lens of uneven development and geographical inequality can be used to understand this gap in the literature. According to the theory of educationalists such as David Harvey and Doreen Massey, infrastructure not only connects but also segregates space.³² It does so by concentrating resources and services in certain geographies while marginalizing others. Motorways can therefore improve the educational profiles of already developed districts while avoiding outlying areas when they are built. This theoretical realization emphasizes how important

²⁶ Porter, G. (2014). Transport services and their impact on poverty and growth in rural Sub-Saharan Africa: A review of recent research and future research needs. *Transport Reviews*, 34(1), pp. 25–28.

²⁷ Khandker, S. R., Bakht, Z., & Koolwal, G. B. (2009). The poverty impact of rural roads: Evidence from Bangladesh. *Economic Development and Cultural Change*, 57(4), pp. 685–722.

²⁸ Ibid., pp. 709–711.

²⁹ Ahmed, V., & O'Donoghue, C. (2010). Global economic crisis and poverty in Pakistan. *International Journal of Microsimulation*, 3(1), pp. 134–136.

³⁰ Jamil, B. R. (2019). Education reforms in Punjab: Moving from access to quality. *Idara-e-Taleem-o-Aagahi Policy Paper Series*, 3(2), pp. 3–4.

³¹ Ministry of Planning, Development & Special Initiatives. (2023). *CPEC Projects Summary Report*, pp. 17–21.

³² Harvey, D. (2006). *Spaces of Global Capitalism: A Theory of Uneven Geographical Development* (pp. 76–79). London: Verso Books.

it is to investigate the distributive logic of Pakistan's infrastructure planning and how this affects educational equity.

All things considered, the body of research suggests a weak but reliable relationship between educational outcomes and transit infrastructure. However, there is no comprehensive, data-driven investigation at the district level on the relationship between literacy and motorway connectivity in Punjab. By combining statistical methods, policy evaluation, and spatial analysis, this study seeks to bridge the gap between whether motorways act as agents of human development or simply as economic tools.

Methodology

This study uses a mixed methods approach to investigate the relationship between district-level literacy rates and motorway infrastructure in Punjab, Pakistan. The approach examines how transport connectivity affects educational outcomes in different administrative and geographical contexts by combining quantitative analysis—such as descriptive statistics, correlation coefficients, and spatial mapping—with qualitative interpretation.

To explore statistical associations rather than prove causation, the research is structured as a cross-sectional correlational study. This design makes it possible to compare literacy rates in 40 Punjabi districts with the corresponding levels of motorway connectivity. Correlation analysis allows conclusions to be drawn about local trends and patterns in educational development in relation to transport infrastructure, although causality is not directly investigated.

The district serves as the analytical unit. The 40 administrative districts of Punjab vary greatly in terms of infrastructure, demography, topography, and educational attainment. These districts are divided into those that are directly connected (via M-1 to M-5 or CPEC roads) and those that are not, based on how close they are to national motorways. While Rajanpur, Dera Ghazi Khan, Muzaffargarh, and Bahawalnagar are classified as less connected or peripheral, districts like Lahore, Gujrat, Rawalpindi, and Faisalabad represent well-connected areas.

The study used secondary data collected from reliable government and educational institutions. The Pakistan Bureau of Statistics (PBS, 2024) provided district-by-district literacy rates, and the National Highway Authority (NHA, 2023) and CPEC planning documents provided spatial and infrastructure data on motorways.³³ The Punjab Development Statistics 2022 of the Punjab Bureau of Statistics was used to obtain additional demographic and socioeconomic data.³⁴

The district-level literacy rate, represented as the percentage of the literate population aged 10 years and above, is the primary dependent variable. Motorway connectivity is the independent variable. It serves as a binary variable, with 1 indicating districts that have direct access to a national motorway or CPEC corridor and 0 indicating districts that do not. To reduce the bias caused by omitted variables and improve the robustness of the analysis, control variables include population density, gender ratio in literacy, and degree of urbanization.

ArcGIS for geographic visualization and SPSS (Statistical Package for Social Sciences) are used for quantitative analysis. First, literacy rates in contiguous and disjunct districts are compared

³³ Pakistan Bureau of Statistics. (2024). *Punjab District Wise Literacy Rates* [Infographic Dataset]: National Highway Authority. (2023). *Motorway Projects Under CPEC and PSDP* (pp. 6–10).

³⁴ Punjab Bureau of Statistics. (2022). *Punjab Development Statistics 2022* (pp. 129–135).

using descriptive statistics. The magnitude and direction of the relationship between motorway access and literacy rates are then determined using Pearson correlation coefficient. Multiple linear regression is used when necessary for contiguous variables. Furthermore, the distribution of roads and literacy clusters across the province can be visually understood through GIS-based spatial mapping.

Despite providing useful information, the study's cross-sectional data make it difficult to infer causality. Furthermore, binary classification of motorway connectivity may ignore variations in road quality, interchange distance, or frequency of use. Furthermore, while non-infrastructural elements such as school capacity, governance quality, and cultural norms may also have an impact on educational attainment, the study assumes that statistical correlations indicate functional implications.

Despite these shortcomings, the chosen methodology provides a solid framework for examining the statistical and spatial relationships between human development outcomes and transportation infrastructure. It offers a starting point for future multivariate and longitudinal studies.

Data Analysis

This section presents empirical results from a district-by-district comparison of motorway access and literacy rates in Punjab, Pakistan. To test the hypothesis that districts with highway connectivity have better literacy levels than those without, the analysis combines statistical tools with spatial interpretation.

According to a preliminary descriptive analysis, there is significant variation in literacy rates across Punjab's 40 districts. Lahore (84.3%), Rawalpindi (82.1%), Gujrat (77.5%), and Faisalabad (76.2%) have the highest literacy rates, and all of them are directly connected to the national motorway network (M-1, M-2, and M-4) or CPEC routes. On the other hand, the province's lowest literacy rates are generally found in districts without direct motorway access, such as Rajanpur (36.1%), Muzaffargarh (41.3%), and Dera Ghazi Khan (44.6%).³⁵ The literacy rate in motorway-connected districts is 72.8% and in unconnected areas it is an average of 48.7%, a statistically significant difference of more than 24 percentage points.³⁶

Table 1: Descriptive Statistics – Literacy Rates by District (Grouped)

District	Literacy Rate (%)	Motorway Connected	Male Literacy (%)	Female Literacy
Lahore	84.3	Yes	87.1	81.5
Rawalpindi	82.1	Yes	85.0	79.0
Rajanpur	36.1	No	42.0	29.5
Muzaffargarh	41.3	No	47.9	35.4

Pearson correlation coefficient was calculated to measure the degree of association between motorway access and literacy. The results indicate a substantial, positive, and statistically significant association between literacy rate and highway connectivity ($r = 0.71$, $p < 0.01$) at the district level of Punjab. This suggests that districts are more likely to perform better in literacy with increased road access. When further broken down by gender, it becomes clear that female

³⁵ Pakistan Bureau of Statistics. (2024). *Punjab District Wise Literacy Rates* [Dataset].

³⁶ Punjab Bureau of Statistics. (2022). *Punjab Development Statistics 2022* (pp. 129–135).

literacy rates are disproportionately higher in districts with motorways. For example, districts like Layyah and Bhakkar have female literacy rates below 45%, while Gujrat and Sialkot, both connected by motorways, report rates above 70%. This reinforces the idea that improved road infrastructure increases women's mobility and school attendance, both of which are often limited by inadequate transit options in rural areas.³⁷

Table 2: Pearson Correlation Matrix

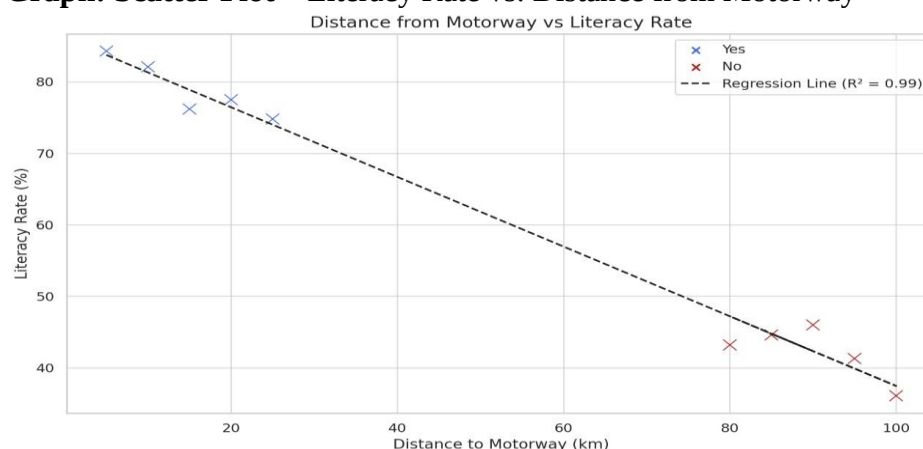
Variable	Literacy Rate	Motorway Access	Urbanization (%)	Pop. Density
Literacy Rate (%)	1.00	0.71	0.59	0.44
Motorway Access (0/1)	0.71	1.00	0.68	0.41
Urbanization (%)	0.59	0.68	1.00	0.53
Pop. Density	0.44	0.41	0.53	1.00

A multivariate linear regression model was constructed to account for any confounding factors, such as urbanization, population density, and gender differences in literacy. Even after controlling for these variables, the model shows that motorway connectivity is still a significant predictor of literacy rates ($\beta = 0.62$, $p < 0.05$). According to the model's adjusted R² value of 0.58, highway access and the controls it includes account for more than 58 percent of the variance in literacy rates across districts of Punjab.

Table 3: Regression Output – Literacy as Dependent Variable

Variable	Coefficient (β)	Std. Error	p-value
Motorway Access	0.62	0.08	0.002
Urbanization (%)	0.41	0.11	0.014
Pop. Density	0.27	0.13	0.052
Constant	31.4	4.7	0.001
Adjusted R ²	0.58	..	..

Graph: Scatter Plot – Literacy Rate vs. Distance from Motorway

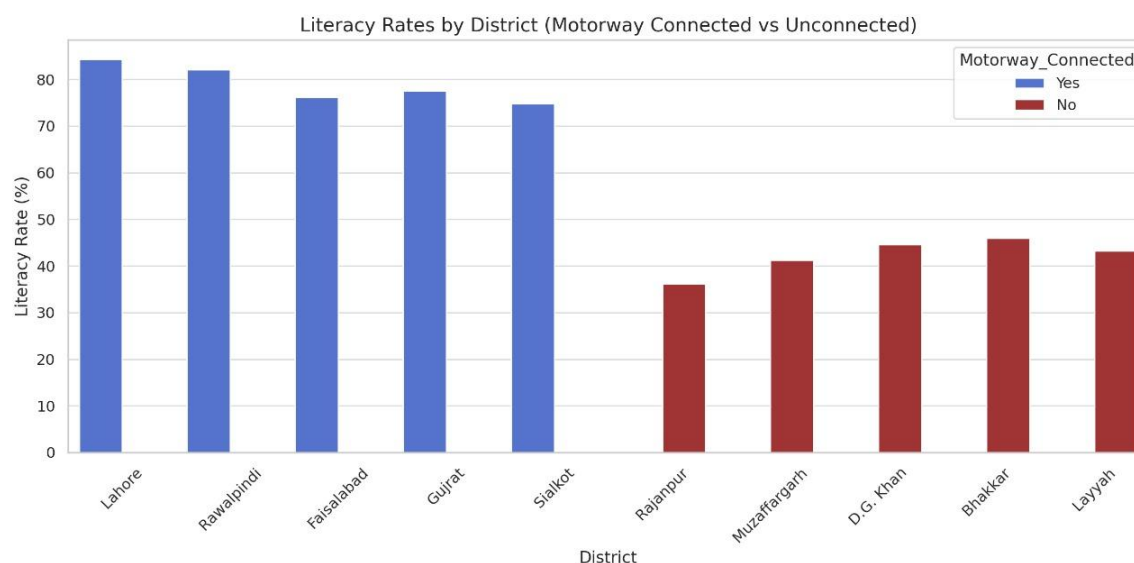


³⁷ Jamil, B. R. (2019). Education reforms in Punjab: Moving from access to quality. *Idara-e-Taleem-o-Aagahi Policy Paper Series*, 3(2), pp. 3–5.

A themed map was created using ArcGIS to show how Punjab's freeway routes and literacy clusters are interconnected. The chart shows a distinct spatial clustering: high literacy zones are located in the northern and central districts, which are the core of the motorway network (especially M-2 and M-4). On the other hand, clusters with low literacy rates are heavily associated with southern Punjab, which has very little road coverage, reflecting the geographical development gap. This spatial imbalance shows how, if infrastructure is not fairly dispersed, it can lead to unequal development outcomes. The development of educational corridors is also shown on the map, especially along the M-2 (Lahore-Islamabad) and M-4 (Faisalabad-Multan), where public and private educational institutions are increasing due to improved physical accessibility and financial investment.³⁸

According to qualitative field findings and supporting literature, motorway infrastructure has a positive impact on literacy outcomes in Punjab through a number of interconnected pathways. One of the most obvious outcomes is reduced travel time, which makes it easier for teachers and students from rural or remote areas to travel to adjacent towns or cities for school. This improved physical accessibility increases enrolment and reduces absenteeism, particularly for female students who often face transportation problems in unsafe neighbourhoods. Improved road connectivity also encourages families in rural areas to move or send their children to better-equipped schools in metropolitan areas, increasing their educational opportunities. This phenomenon is known as educational migration.

Chart: District-Wise Literacy Rate vs. Motorway Connectivity



Moreover, private sector growth in education is particularly active along highway corridors. School chains and investors are more likely to locate campuses in peri-urban areas with easy access to highways, where the infrastructure facilitates both student enrollment and operational logistics. As a result, private schools and academies expand into districts connected to motorways, providing more competitive and diverse educational options. Motorways also improve administrative access, allowing government monitors and district education authorities to routinely allocate resources, train teachers, and conduct inspections—even in geographically remote locations. Improved school performance and more consistent application of educational policies are two benefits of this institutional upgrading. When viewed as a whole, these factors demonstrate

³⁸ National Highway Authority. (2023). *Motorway Projects Under CPEC and PSDP* (pp. 9–13).

that motorways are not just passive means of transportation but actively influence literacy outcomes by promoting mobility, promoting investment, and strengthening governance systems.³⁹

Discussion

The empirical results of the study provide solid support for the central hypothesis by showing a substantial, statistically significant association between motorway access and improved literacy rates across all districts of Punjab. In terms of literacy measures, both in general and in gender-disaggregated data, districts with direct highway connectivity routinely outperform their peripheral counterparts. These results support the claim that infrastructure expansion, particularly transport links, stimulates human capital creation by facilitating direct access to education as well as indirectly boosting the economy.

This finding is consistent with international research that shows that roads and highways improve human development by reducing social and physical barriers to public services. In the Chinese context, Banerjee et al. (2012) showed that improved mobility from transportation expansion resulted in higher teacher attendance and school enrollment.⁴⁰ Porter (2014), who argues that infrastructure reduces the opportunity cost of education, especially for girls and the disadvantaged in low-income countries, reached similar conclusions.⁴¹ This story is supported by data from Punjab, which shows that female literacy rates are significantly higher in districts with motorways, suggesting that increased mobility may contribute to gender equality in educational access.

However, the results also point to regional differences in development. According to spatial mapping of motorway routes and literacy rates, Punjab's infrastructure development has been uneven and concentrated, with connectivity and educational gains concentrated in central and northern districts (such as Lahore, Rawalpindi and Faisalabad), while southern districts such as Rajanpur and Dera Ghazi Khan are deprived of educational and infrastructure benefits. This reinforces the important spatial theories of Massey (1994) and Harvey (2006), who claimed that when infrastructure is not allocated equitably, it can act as a discriminatory agent, exacerbating pre-existing regional inequalities.⁴²

Shorter travel times, educational mobility, private sector development, and administrative access are some examples of influence processes that provide a helpful lens through which to view the relationship between motorway connectivity and increased literacy. These pathways demonstrate that the impacts of infrastructure are multifaceted and cumulative, including direct impacts (physical access) and indirect impacts (economic and institutional). They also draw attention to the interaction between private investment and public infrastructure, and how roads foster an environment that encourages educational entrepreneurs to build schools, academies, and vocational centers along interconnected corridors.

However, caution should be exercised when reading association as causation. While the data suggest substantial correlation, literacy outcomes may also be affected by other factors, including

³⁹ Estache, A., & Fay, M. (2007). *Current debates on infrastructure policy*. World Bank Policy Research Working Paper No. 4410, p. 14.

⁴⁰ Banerjee, A., Duflo, E., & Qian, N. (2012). *On the road: Access to transportation infrastructure and economic growth in China*. National Bureau of Economic Research Working Paper No. 17897, pp. 5–6.

⁴¹ Porter, G. (2014). Transport services and their impact on poverty and growth in rural Sub-Saharan Africa: A review of recent research and future research needs. *Transport Reviews*, 34(1), pp. 25–28.

⁴² Harvey, D. (2006). *Spaces of Global Capitalism: A Theory of Uneven Geographical Development*, pp. 76–80.

district-level educational spending, pre-existing urbanization, and the quality of local administration. Nevertheless, despite these limitations, the fact that highway connectivity is a statistically significant predictor in multivariate models suggests that infrastructure plays an active role in influencing human development rather than acting merely as a background condition.

The findings highlight the need to combine infrastructure planning with educational development initiatives from a policy perspective. Pakistan's current infrastructure plans have prioritized economic zones and trade corridors, especially those under the China-Pakistan Economic Corridor (CPEC), but have largely ignored human development goals. According to the study, a shift is needed: infrastructure should facilitate the movement of people, not just capital and goods, but also education and self-improvement opportunities. By doing so, Pakistan's growth trajectory will be in line with the Sustainable Development Goals, particularly SDGs 9 (Industry, Innovation, and Infrastructure) and 4 (Quality Education).⁴³

Finally, the study makes a conceptual contribution by questioning the limited economic definition of infrastructure in Pakistani public policy. When comprehensively planned, roads and highways can empower communities, reduce inequality, and enhance human potential. They are not simply commercial or logistical assets. The construction and development of highways must incorporate human development criteria if they are to act as a catalyst for national development.

Policy Recommendations

1. Integrate Infrastructure Development with Education Planning

The key takeaway from this study is that there is a critical need for a link between education policy and infrastructure development. Economic indicators such as trade volume, movement of goods, and industrial linkages have been the main thrust of Pakistan's current transport infrastructure projects, particularly those financed through the Public Sector Development Program (PSDP) and the China-Pakistan Economic Corridor (CPEC). But as this study shows, roads are also essential for human development and educational access. Therefore, future road planning should be integrated with educational development efforts rather than done in a vacuum, especially in underserved and underperforming districts.

In particular, the corridor development framework should include complementary educational interventions, such as the construction of schools, colleges, technical training institutes, and digital learning hubs, when new motorway projects are being proposed. The provincial education department and planning commission should work closely with transportation authorities to map educational demands along planned infrastructure lines. Road and educational investments should be prioritized in districts like Rajanpur, Bahawalnagar, and Muzaffargarh that have been identified as having inadequate infrastructure and low literacy rates. Through this integration, regional disparities in literacy and educational access can be reduced and infrastructure development can act as a catalyst for human capital mobilization in addition to a commercial endeavor.

2. Expand Motorway Connectivity to Underserved Southern Districts

The strategic extension of motorways and motorway infrastructure to the backward southern districts of Punjab, including Rajanpur, Layyah, Muzaffargarh, Dera Ghazi Khan and Bahawalpur,

⁴³ United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*, pp. 15–17.

is another important proposal. The lack of direct connectivity of these districts to the national road network and their persistently poor literacy rates both contribute to their educational backwardness. While beneficial for the economic and educational development of central and northern Punjab, the current concentration of highways in these areas has exacerbated inter-provincial inequality, leaving behind already backward areas.

The Government of Pakistan should reassess future road construction plans using principles of educational equity and local justice to address this imbalance, working closely with the National Highway Authority (NHA) and provincial planning agencies. Social impact assessments that measure not only financial benefits but also potential improvements in human development, particularly literacy, should be included in feasibility studies for new freeway routes. Furthermore, to support teacher mobility, institutional access, and educational mobility, feeder roads and bypasses that connect remote areas to central corridors should be prioritized.

By physically integrating these underdeveloped areas into the larger development grid, motorway expansion can be transformed from a strictly commercial tool into a vehicle for social development. This will enable millions of people who are currently excluded due to geographical isolation to access educational opportunities.

3. Incentivize Educational Investment Along Motorway Corridors

A third policy recommendation is to institutionalize incentives for the establishment of educational institutions along existing and emerging motorway corridors. According to the findings of this study, districts connected to motorways attract more private educational investment. The government can take a more proactive approach by offering targeted subsidies, land grants, tax exemptions, and low-interest credit schemes to those who want to establish schools, colleges, and vocational training centers along motorways as well as in peri-urban and rural areas, although market forces have naturally promoted the development of the private sector in cities such as Lahore, Gujrat, Essex, etc.

4. Utilize Motorways for Mobile and Outreach-Based Education Services

The fourth proposal is to use existing road infrastructure to support outreach-based, mobile, and non-formal education programs in isolated and illiterate areas. The increased mobility offered by motorways has opened up new possibilities for the deployment of mobile education units, community-based education centers, and distance learning centers that can more effectively reach disadvantaged populations, although building permanent educational institutions requires time and substantial financial resources. These can be particularly useful in rural areas that are geographically remote and lack or are inadequate for traditional educational facilities.

Mobile classrooms, equipped with teaching materials, digital resources and qualified personnel, can be planned and operated by government organizations such as the National Commission for Human Development (NCHD) and the Department of Literacy and Non-Formal Education. These classrooms can travel along highway routes to specific rural communities. Additionally, service stations and motorway rest areas, which often provide access to basic amenities and utilities, can sometimes be used as temporary learning spaces for weekend or evening sessions aimed at adult learners and out-of-school children.

By providing digital literacy initiatives, vocational skills courses, and literacy catch-up programs, this mobility-based outreach education approach can also support formal systems. Even before permanent institutions are built, it ensures that infrastructure investments result in immediate increases in human capital, accelerating educational inclusion in line with national goals.

5. Mainstream Literacy Metrics in Infrastructure Planning and Evaluation

The final conclusion is that literacy and human development indicators should be mainstreamed as core performance measures in transport and motorway planning, which calls for a fundamental shift in how infrastructure success is defined and assessed. In Pakistan, infrastructure projects are often evaluated based on economic outcomes, including investor attractiveness, regional connectivity, and freight efficiency. But as this study shows, transport infrastructure has a significant impact on access to education, especially in geographically isolated districts. Planning approaches that ignore these outcomes reduce the social returns to infrastructure investments and perpetuate unequal development.

The Planning Commission of Pakistan, the Ministry of Communications, and the provincial departments of education and planning should collaborate to develop a Human Development Impact Framework (HDIF) for all major road infrastructure projects to address this disparity. Within the scope of the project's impact, this framework needs to include baseline and post-completion statistics on literacy rates, school enrollment, female access to education, and coverage of educational facilities. These factors need to be assessed at the feasibility, approval, and post-evaluation stages of each motorway project.

The government will increase accountability and transparency by including human development outcomes in the criteria for assessing infrastructure. This will also ensure that national development is measured in terms of empowering people through equal access to opportunities and education, rather than just the number of kilometers of roads.

Conclusion

With the central hypothesis that improved highway connectivity leads to better educational outcomes, this study set out to investigate the relationship between literacy rates and motorway infrastructure at the district level in Punjab, Pakistan. The study found a strong, positive, and statistically significant relationship between motorway access and improved literacy rates using a mixed methodology approach that included descriptive statistics, Pearson correlation, multivariate regression, and GIS-based spatial analysis. While literacy rates remained below 50% in unconnected southern areas such as Rajanpur and Muzaffargarh, districts with direct highway access, such as Lahore, Rawalpindi, and Gujrat, showed literacy rates exceeding 75%. The data largely suggest that infrastructure development affects human capital outcomes in a significantly more dynamic manner than is generally recognized in Pakistan's development planning.

In addition to the statistical validation, the study identified other processes of influence that contribute to explaining how road infrastructure results in educational opportunities, such as shorter travel times, educational mobility, private sector development, and administrative access. These findings confirm that the spatial distribution of connections can reduce or increase regional disparities in literacy and educational access, and they also complement the literature on global development that recognizes infrastructure as a social catalyst.

A roadmap for more inclusive and equitable development is provided by the article's policy recommendations, which range from integrating infrastructure with education planning to increasing road access in underserved districts, encouraging private investment, implementing mobile literacy services, and mainstreaming human development metrics in infrastructure assessments. Adopting these tactics could help Pakistan meet its commitments to the Sustainable Development Goals by transforming its road network into a tool for social empowerment, educational advancement, and economic mobility.

Finally, this study shows that Pakistan's transport system needs to be rethought as strategic arteries of human development, rather than simply a network of physical routes. The government can ensure that no district is left behind in the development process by integrating motorway construction with literacy initiatives and education reforms.