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# *Population Characteristics and Transport Infrastructure Access: Evidence from Village-Level Data in India*

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***Abstract.*** Rapid population growth and uneven transport infrastructure development remain pivotal challenges in many developing countries. This study examines the relationship between population characteristics and transport infrastructure. The data used in the study is the village-level data from the Socioeconomic High-resolution Rural-Urban Geographic (SHRUG), a database in India.. Transport infrastructure is measured by five indicators: paved roads, bus services, national highways, state highways, and major district roads. Population density is the main explanatory variable, while the number of households and total population are included as robustness checks. Linear Probability Models (LPM) are used for the main analysis. The results show that population density is positively associated with all five measures of transport infrastructure. Similar positive relationships are found when the number of households and total population are used as alternative population measures, supporting the robustness of the findings. These results indicate that villages with larger populations are more likely to have better transport infrastructure. This study provides empirical evidence that population characteristics are closely associated with transport infrastructure development. The findings highlight the importance of considering population distribution in infrastructure planning and may provide useful insights for transport policy and balanced regional development in developing countries.

***Keywords:*** transport, infrastructure, population, development, developing countries

## 1. Introduction

Development inequality remains a significant challenge in many parts of the world, especially in developing regions. Although the growth of economic snf reduction of poverty happened in the past few decades, Sub-Saharan Africa still struggles with consistent development gaps. I Many areas hard to build adequate infrastructure or deliver basic public services, that's because the inequal resource distribution and limited institutional capacity. So inequality continues to shape the region's landscape. Meanwhile, Africa is experiencing rapid population growth and urbanization.. Nowadays, Africa has some of the highest urban growth rate globally, cities are expending at an incredible pace. This surge places raise pressure on urban governance and local service systems. With the increasing growth of urban populations, the demand for housing also increases. But , many low income residents cannot afford formal housing in city centers and are often forced to move to poor areas. Thus, informal settlements and slums have expanded across many African cities.

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Poor housing, limited sanitation, and unsafe drinking water lead serious risks to health, income generation, and well-being. Improving basic facilities is an essential step t addressing these urban problems. Among public facilities, the transport system is a key factor. It connects people with employment opportunities, education, healthcare, and other basicl services. In this study, transport infrastructure refers to public transport availability, road networks, and spatial accessibility. Understanding the key factors that influence transport infrastructure development is important for promoting sustainable urban development in Sub-Saharan Africa.

## 2. Conceptual framework

### 2.1. Background

Transport infrastructure refers to the physical and organizational network that enables the movement of people and goods between different locations [1]. It contributes to supporting regional development by improving accessibility, creating employment opportunities, and facilitating economic activities [2]. In this study, transport infrastructure is examined from three dimensions: public transport availability, road infrastructure, and distance to the urban center. These dimensions reflect different aspects of transport accessibility and connectivity and are used to evaluate transport infrastructure development.Transport infrastructure development is shaped by factors such as economic conditions, political institutions, financing capacity, technological progress, and urbanization [3]. However, the influence of population characteristics, especially population size and density has received less attention.

This study examines the relationship between population characteristics and transport infrastructure. India shares several development challenges with Sub-Saharan African countries, including rapid population growth, urbanization, and uneven infrastructure development. Using the SHRUG dataset, this study investigates whether population density and population size are connected with transport infrastructure development.

### 2.2. Literature review

Previous studies have indicated that population size and population density are closely related to transport system development. As population increases, travel demand tends to rise accordingly, bringing greater pressure on existing transport systems and creating the need for further infrastructure provision. Previous studies have shown that population growth is one of the key drivers of future transport demand, and that the spatial distribution of population growth also matters, as urban expansion in peripheral areas tends to increase travel distances and infrastructure requirements [4].

Beyond transport demand, population densityare related to transport infrastructure development. Glover and Simon provide practical evidence that population density has a significant and positive effect on road infrastructure, showing that higher density is associated with greater road construction, specially paved roads [5]. This demonstrates that population concentration can directly influence infrastructure investment and development patterns in transport networks.

In addition, population density is also associated with transport mode choice and public transport usage. Dargay and Hanly find that people living in high-density areas are more likely to use public transport, while those in low-density areas rely more heavily on private vehicles [6]. This indicates that population density not only affects transport demand but also shapes transportation system in reality.

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Overall, existing literature reveals that population size and density are considerable determinants of transport systems. They affect transport demand and shape mode choice.They also related to the development of road networks. This evidence provides a theoretical foundation for examining how population characteristics affect public transport availability, road infrastructure, and spatial accessibility in Sub-Saharan African cities.

. Developing counties are stuck with rapid urbanization. The developing speed of adequate housing, public services and infrastructure offered by government are left beyond by increasing population and expanding city scales. Previous research argued that this rapid urban growth has contributed to the expansion of informal settlements, where residents often have limited access to basic infrastructure and public services [7].

Infrastructure development in informal settlements is often constrained by weak land governance and fragmented urban planning. Winayanti and Lang argued that insecure land tenure, poor coordination among government levels, and limited policy implementation hinder infrastructure and urban service provision in these areas [8]. Effective infrastructure development not only needs better land management, but also stronger cooperation between governments and local communities. Therefore, although population growth increases demand for transport, rapid urbanization and planning constraints might be obstacle for infrastructure from keeping pace.

Recent scholarly works further prove that transport infrastructure development is influenced by population growth and urbanizationand the quality of urban governance. Cirolia and Harber argue that transport governance in African cities involves multiple actors, including different levels of government, private organisations, community groups, and other institutions [9]. As a result, transport planning and infrastructure provision are not matched, thus it's difficult to respond effectively to rapidly growing urban populations. These findings demonstrate that governance capacity determines whether transport demand can be translated into infrastructure development. Therefore, understanding the relationship between population and transport infrastructure requires considering both demographic factors and the institutional context in which infrastructure is planned and delivered.

## 3. Data and method

### 3.1. Data

The Socioeconomic High-resolution Rural-Urban Geographic Dataset on India (SHRUG) is an open-source database developed by Development Data Lab that provides village- and town-level socioeconomic information across India with harmonized geographic boundaries. SHRUG is very suitable for this study, it gives detailed village level information. For example, population, households, transport infrastructure, electricity, and geographic accessibility. —These variables offer a comprehensive basis for examining the relationship between population characteristics and transport infrastructure across Indian villages.

The outcome variable in this study is transport infrastructure. According to the SHRUG database, transport infrastructure is measured by five binary indicators. These variables respectively indicate whether a village has a paved road, bus service, national highway, state highway, or major district road. Each variable takes the value of 1 if the corresponding infrastructure is available and 0 otherwise.

The main explanatory variables describe village-level population characteristics. Population density is measured by dividing total population by village size, household count is represented by total number of households in a village, and total population is captured using total population. To

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reducing the effects of skewed distributions, the explanatory variables are transformed using natural logarithms before the regression analysis.

Several control variables account for regional and socioeconomic differences across villages. Specifically, state fixed effect is used to control state-level differences, electricity availability indicates whether a village has access to electricity. This study also controls the average nighttime light intensity as a proxy for local economic development, and the distance from the village to the nearest town.

### 3.2. Analytical approach

To examine the relationship between population characteristics and transport infrastructure, this study employs a Linear Probability Model (LPM) as the main analytical approach. The model estimates how population factors are associated with the availability of transport infrastructure while controlling other village characteristics. To test the robustness of the findings, logistic regression models are also adopted. Comparing the results from the two models helps assess the consistency and reliability of the practical results.

## 4. Result

### 4.1. Summary statistics

Table 1 reports the distribution of outcome variables. Among the sample, 62.59 percent of villages have paved road. Among the sampled villages, paved roads are present in 62.59% of cases, making them the most frequently observed type of transport infrastructure. Bus services follow, available in 44.32% of the villages. In contrast, major district roads are found in only 27.93% of the sample, while state highways and national highways are considerably less common, covering 15.09% and 6.15% respectively. Taken together, these figures point to a rather uneven distribution of transport infrastructure across villages, with some types being widely accessible and others remaining quite limited.

Table 1. Distribution of outcome variables

| Variables | *Frequency (N)* | *Percentage (%)* | *Sample Size (N)* |
|---|---|---|---|
| Paved road | | | 588,445 |
| Yes | 368,281 | 62.59 | |
| No | 220,164 | 37.41 | |
| Has bus | | | 588,518 |
| Yes | 260,842 | 44.32 | |
| No | 327,676 | 55.68 | |
| Has national highway | | | 588,293 |
| Yes | 36,171 | 6.15 | |
| No | 552,122 | 93.85 | |
| Has State highway | | | 588,284 |

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Table 1. (continued)

| | | | |
|---|---|---|---|
| Yes | 88,744 | 15.09 | |
| No | 499,540 | 84.91 | |
| Has major district road | | | 588,233 |
| Yes | 164,321 | 27.93 | |
| No | 423,912 | 72.07 | |

Table 2 reports the distribution of explanatory variables.

Table 2. Distribution of explanatory variables

| Variables | *Mean* | *SD* | *Maximum* | *Minimum* | *Sample size* |
|---|---|---|---|---|---|
| Population density | 671.921 | 1,702.876 | 361,174.3 | 0.0015274 | 596,358 |
| Number of households | 418.3109 | 7,869.497 | 3,435,999 | 1 | 596.393 |
| Total population | 2,030.107 | 36,131.61 | 1.68e+07 | 1 | 596.393 |

Table 2 reports the descriptive statistics of the explanatory variables. The average population density is 671.92 persons per unit, although the large standard deviation (1,702.88) indicates substantial variation across villages. On average, villages contain 418 households and approximately 2,030 residents. The wide ranges and large standard deviations of these variables suggest considerable differences in village size and population characteristics within the sample.

## 4.2. Main results

Table 3. The effect of population density on transport infrastructure

| Variables | *Paved road* | *Bus* | *National highway* | *State highway* | *Major district road* |
|---|---|---|---|---|---|
| Population density | .0000112*** (3.74e-07) | .0000112*** (3.80e-07) | 4.10e-06*** (2.21e-07) | 7.27e-06*** (3.28e-07) | .0000102*** (4.04e-07) |
| Has electricity | .1195189*** (.0014343) | .15256*** (.0014554) | .0235566*** (.0008455) | .0547382*** (.0012557) | .0789158*** (.0015477) |
| Night light index | .0082323*** (.0003519) | .005515*** (.0003572) | .0102008*** (.0002075) | .0102311*** (.0003081) | .0111539*** (.0003798) |
| Distance to town center | -.0021042*** (.0000265) | -.0008984*** (.0000269) | -.0005166*** (.0000156) | -.0007814*** (.0000232) | -.0010384*** (.0000286) |
| $R^2$ | 0.254 | 0.296 | 0.018 | 0.036 | 0.049 |
| *N* | 518,49 | 518,57 | 518,53 | 518,52 | 518,48 |

Note: * P<0.05 **P<0.01 ***P<0.001. Each cell represents

Table 3 presents the main effects of population density on different types of transport infrastructure using the Linear Probability Model. Population density is positively and statistically significantly associated with all five transport infrastructure indicators.

For paved roads, the coefficient of population density is 0.0000112 (SE = 3.74e-07, $p < 0.001$), point to villages with higher population density are more likely to have paved roads. Similar positive relationships are observed for bus services ($\beta = 0.0000112$, SE = 3.80e-07), national highways ($\beta =$

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4.10e-06, SE = 2.21e-07), state highways (β = 7.27e-06, SE = 3.28e-07), and major district roads (β = 0.0000102, SE = 4.04e-07). All estimated coefficients are statistically significant at the 0.1% level.

## 4.3. Robustness check

Table 4. The effect of the number of households in the village on transport infrastructure

| Variables | *Paved road* | *Bus* | *National highway* | *State highway* | *Major district road* |
|---|---|---|---|---|---|
| Number of households | 3.01e-06 *** (1.83e-07) | 3.57e-06*** (1.86e-07) | 9.77e-07*** (1.08e-07) | 2.12e-06*** (1.60e-07) | 2.83e-06*** (1.98e-07) |
| Has electricity | .1200909*** (.001435) | .1530846*** (.001456) | .0237779*** (.0008457) | .0550956*** (.001256) | .0794305*** (.0015482) |
| Night light index | .0088901*** (.0003512) | .0061164*** (.0003564) | .0104548*** (.0002069) | .0106409*** (.0003074) | .0117441*** (.0003789) |
| Distance to town center | -.0021253*** (.0000265) | -.0009188*** (.0000269) | -.0005244*** (.0000156) | -.0007949*** (.0000232) | -.0010575*** (.0000286) |
| $R^2$ | 0.253 | 0.296 | 0.018 | 0.035 | 518,48 |
| *N* | 518,49 | 518,57 | 518,53 | 518,52 | 0.048 |

Note: * P<0.05 **P<0.01 ***P<0.001. Each cell represents

Table 5. The effect of total population on transport infrastructure

| Variables | *Paved road* | *Bus* | *National highway* | *State highway* | *Major district road* |
|---|---|---|---|---|---|
| Total population | 9.19e-07*** (4.51e-08) | 1.08e-06*** (4.57e-08) | 2.93e-07*** (2.66e-08) | 6.37e-07*** (3.94e-08) | 8.38e-07*** (4.86e-08) |
| Has electricity | .1199389*** (.0014348) | .1529094*** (.0014558) | .0237308*** (.0008457) | .0549929*** (.0012559) | .0792989*** (.0015481) |
| Night light index | .0087941*** (.0003512) | .0060074*** (.0003564) | .0104259*** (.000207) | .0105774*** (.0003074) | .0116648*** (.0003789) |
| Distance to town center | -.0021242*** (.0000265) | -.0009176*** (.0000269) | -.0005241*** (.0000156) | -.0007942*** (.0000232) | -.0010566*** (.0000286) |
| $R^2$ | 0.254 | 0.296 | 0.018 | 0.035 | 0.049 |
| *N* | 518,49 | 518,57 | 518,53 | 518,52 | 518,48 |

Note: * P<0.05 **P<0.01 ***P<0.001. Each cell represents

Tables 4 and 5 present robustness checks by replacing the main explanatory variable, population density, with two alternative measures of population: the number of households and total population. If the estimated effects remain similar, the main findings can be considered robust.

As shown in Table 4, the number of households is positively and significantly associated with all five transport infrastructure indicators ($p < 0.001$). Villages with more households are more likely to have paved roads, bus services, state and national highways, and main district roads. These results are consistent with the main findings using population density, suggesting that larger settlements tend to have better transport infrastructure.

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Table 5 replaces population density with total population. The results remain positive and statistically significant across all five transport infrastructure indicators ($p < 0.001$). Villages with larger populations are more likely to have better transport infrastructure. The consistency of the results across different measures of population provides further support for the main findings.

Overall, the robustness checks carry the implication that the positive relationship between population and transport infrastructure is stable no matter whether population is measured by density, the number of households, or total population.

## 5. Discussion

This study finds that population characteristics are positively bound up with transport infrastructure at the village level in India. Villages with higher population density tend to have more rounded infrastructure. Similarly, replacing population density with the number of households or total population gives comparable positive coefficients. It means that our results are robust to alternative measures of population size. These results align with the hypothesis proposed in this study and with previous literature; larger populations create more demand for transport infrastructure. One possible explanation is governments are have more probability to invest transport infrastructure in areas where more people can benefit. Allowing infrastructure provision to be more efficient. The consistency of the results across multiple population and transport indicators provides further support for the proposed hypothesis; suggests that population characteristics should be considered when planning transport infrastructure in developing countries.

### 5.1. Implications

One important implication of this study is transport infrastructure should not be allocated solely according to population size. Although areas with larger populations are more likely to receive transport investment, governments should continue supporting transport development in low-population and remote areas. Access to transport is closely to access to education, healthcare, employment, and other public services. Improving transport infrastructure in inequal regions can bring more equal development opportunities, particularly for poor communities, ethnic minority areas, and left-behind populations.

The findings also have implications for regional development. Better transport infrastructure can lead to economic boosts, such as market access and business opportunities. As economic development encourages population growth, a positive cycle between transport infrastructure and regional development may occur. However, regions with poor transport infrastructure goanna go through slow economic growth and population loss, widening regional development imbalance. Therefore, governments should discuss more balanced infrastructure investment strategies to reduce long term regional difference rather than assigning resources only rely on current population size.

### 5.2. Limitations

This study have several limitations. First, the findings identify correlation between population characteristics and transport infrastructure. Although significant positive relationships are observed, the regression analysis cannot recognize whether demographic characteristics cause improvements in transport infrastructure directly. Second, the empirical analysis is based on village-level data from India. While India shares many development characteristics with other developing countries, such as high speed population growth and unequal infrastructure development; it requires further

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examination if it needs to be widely used to other countries. Third, this study may still be subject to omitted variable bias. Factors such as local government investment or geographical conditions may influence both population characteristics and transport infrastructure, but are not fully captured in the analysis. Nevertheless, the robustness check using alternative measures of population show consistent results; suggesting that the observed associations are stable and meaningful.

## 6. Conclusion

This study examines the relationship between population characteristics and transport infrastructure using village-level data from India. The findings show that villages with higher population density, more households, and larger populations are more likely to have better transport infrastructure. These results support the theoretical framework and show that population is an important factor in transport infrastructure development.

Although this study focuses on India, the implications may also provide useful insights for other developing countries, who is facing similar challenges. Transport infrastructure should not only respond to current population demand, but also support more balanced and inclusive regional development. Future research could use data from other countries and more recent statistics to further examine these relationships, and provide stronger evidence for infrastructure planning and public policy.

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