Assessing Sustainable Infrastructure Disparities in Srinagar City: A Data-Driven Multivariate Analysis

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Abstract

This study examines spatial disparities in sustainable infrastructure across the tehsils of Srinagar city, an ecologically fragile urban region experiencing rapid and unplanned urbanization. Using a mixed-method approach, it combines quantitative analysis through Principal Component Analysis (PCA) with qualitative insights from semi-structured interviews. A Composite Sustainable Infrastructure Index (SII) is constructed using twelve indicators across physical, social, environmental, and basic service dimensions. The results show that the first three components explain over 72% of the total variance, with physical infrastructure and basic services emerging as key drivers of inequality. The findings reveal a clear core–periphery divide, where central tehsils such as Srinagar Central and Khanyar demonstrate higher levels of infrastructure development, while peripheral areas like Eidgah and Panthachowk remain underserved. Qualitative evidence supports these results, highlighting deficiencies in water supply, sanitation, and road connectivity in low-ranking regions, alongside issues of congestion and environmental stress in high-ranking areas. Environmental sustainability emerges as a weakly integrated dimension, reflecting fragmented urban planning. The study identifies governance gaps, limited participation, and unequal resource allocation as major contributors to these disparities. It calls for decentralized, inclusive, and environmentally sustainable infrastructure planning, supported by stronger institutions and data-driven decision-making. The findings offer important policy insights for promoting balanced and sustainable urban development

Keywords: Sustainable: Infrastructure; Spatial Inequality; Principal Component Analysis (PCA); Composite Index; Urban Development; Core-Periphery; Environmental Sustainability; Urban Governance

1. Introduction

Urbanization has emerged as one of the most defining processes of the 21st century, fundamentally transforming the spatial, economic, and environmental dynamics of cities across the globe. In developing regions, this transformation is often characterized by rapid and unplanned expansion, leading to uneven distribution of infrastructure and growing sustainability concerns. Sustainable infrastructure encompassing physical, social, environmental, and service dimensions is increasingly recognized as a critical determinant of urban resilience and inclusive development (World Bank, 2017). However, the benefits of infrastructure development are rarely distributed evenly, resulting in pronounced spatial disparities within cities. These disparities not only reflect structural inequalities in access to services but also contribute to environmental degradation and socio-economic marginalization.

In the context of India, urban growth has been marked by a strong core-periphery pattern, where central urban areas tend to attract higher levels of investment, better infrastructure, and improved service delivery, while peripheral regions lag behind (Krugman, 1991). This uneven development is particularly evident in medium-sized and ecologically sensitive cities, where rapid urbanization occurs without adequate planning frameworks. As a result, infrastructure expansion often prioritizes economic and administrative centers, leaving peripheral zones underserved and environmentally vulnerable. Such patterns reinforce existing inequalities and hinder the realization of sustainable urban development goals.

Srinagar, the summer capital of Jammu and Kashmir, presents a compelling case for examining these dynamics. Historically celebrated as the “city of lakes,” Srinagar is characterized by a unique ecological setting, including wetlands, river systems, and interconnected water bodies that have traditionally supported livelihoods and environmental balance. However, in recent decades, the city has undergone significant spatial transformation driven by population growth, tourism, and policy-driven urban expansion. This transformation has resulted in unregulated urban sprawl, encroachment on wetlands, and increasing pressure on existing infrastructure systems (Haq et al., 2015). Empirical evidence suggests that Srinagar has lost a substantial proportion of its wetlands over the past three decades, significantly reducing its natural capacity for flood absorption and environmental regulation (Wetlands International South Asia, 2022; WUCMA, 2021).

The uneven distribution of infrastructure within Srinagar further complicates this scenario. Central tehsils, which serve as administrative and commercial hubs, tend to exhibit higher levels of infrastructure development, including better road networks, water supply systems, and access to education and healthcare services. In contrast, peripheral and semi-urban tehsils often experience deficits in basic services such as sanitation, waste management, and reliable water supply. This spatial inequality not only affects the quality of life of residents but also exacerbates environmental risks, particularly in low-lying and ecologically fragile areas. The catastrophic floods of 2014, for instance, highlighted the consequences of unplanned urban development and the neglect of natural drainage systems (Haq et al., 2015).

Despite the growing recognition of these challenges, much of the existing literature on Srinagar focuses on environmental degradation, urban sprawl, or policy analysis in isolation. There is a notable lack of quantitative, data-driven studies that examine infrastructure disparities at a disaggregated spatial level, particularly across tehsils. Moreover, traditional approaches often rely on single indicators, which fail to capture the multidimensional nature of sustainable infrastructure. In this context, multivariate statistical techniques such as Principal Component Analysis (PCA) offer a robust framework for integrating multiple indicators into a composite index, enabling a more comprehensive assessment of spatial inequality (Filmer & Pritchett, 2001).

Against this backdrop, the present study seeks to bridge this gap by conducting a data-driven, multivariate analysis of sustainable infrastructure disparities across tehsils of Srinagar city. By constructing a Composite Sustainable Infrastructure Index (SII) using PCA, the study provides a nuanced understanding of how different dimensions of infrastructure interact and vary spatially. The analysis not only identifies high- and low-performing regions but also sheds light on the underlying structural factors driving these disparities. In doing so, the study contributes to the broader discourse on sustainable urban development by emphasizing the need for balanced, inclusive, and environmentally sensitive infrastructure planning in ecologically fragile urban contexts.

The remainder of the paper is structured as follows. Section II presents a comprehensive review of the relevant literature. Section III outlines the research methodology and data sources employed to achieve the objectives of the study. Section IV provides the empirical findings along with a detailed discussion of the results. Finally, Section V concludes the study by presenting key policy implications and recommendations.

2. Literature Review

The study of sustainable infrastructure and its spatial distribution have gained increasing attention in urban economics, development studies, and environmental planning. The concept of infrastructure has evolved beyond physical assets to include social services, environmental sustainability, and institutional efficiency, making it a multidimensional construct central to urban development (World Bank, 2017). However, the distribution of such infrastructure is often uneven, leading to spatial disparities that reinforce socio-economic inequalities within cities. On of the foundational theoretical perspectives explaining spatial inequality is the core-periphery model, which posits that economic activities and infrastructure tend to concentrate in central regions, leaving peripheral areas underdeveloped (Krugman, 1991). This model has been widely applied in urban studies to explain the clustering of infrastructure and services in metropolitan cores. Empirical studies have shown that such concentration leads to cumulative advantages for central areas, including better access to transportation, healthcare, and education, while peripheral regions face persistent deficits (Fujita, Krugman, & Venables, 1999). In the context of developing countries, this pattern is often exacerbated by policy biases and resource constraints, resulting in uneven urban development. The measurement of infrastructure disparities has increasingly relied on composite indices that capture multiple dimensions of development. Traditional single-indicator approaches are inadequate for understanding the complexity of infrastructure systems. In this regard, Principal Component Analysis (PCA) has emerged as a widely used technique for constructing composite indices by reducing dimensionality and identifying key underlying factors (Jolliffe, 2002). Filmer and Pritchett (2001) demonstrated the effectiveness of PCA in constructing wealth indices using household asset data, highlighting its applicability in contexts where direct income or expenditure data is unavailable. Similarly, Nagar and Basu (2002) emphasized the importance of multivariate techniques in capturing regional disparities in development indicators. In urban infrastructure studies, PCA has been applied to assess disparities in access to basic services such as water supply, sanitation, and electricity. For instance, Sahn and Stifel (2003) used PCA to analyze poverty and infrastructure access in African countries, finding significant inequalities in service delivery across regions. In the Indian context, several studies have utilized PCA to construct indices of urban infrastructure and quality of life, revealing substantial inter-regional and intra-urban disparities (Kundu & Sarangi, 2007). These studies underscore the importance of adopting a multidimensional approach to infrastructure assessment. Environmental sustainability has also emerged as a critical dimension of infrastructure studies, particularly in ecologically sensitive regions. Rapid urbanization often leads to environmental degradation, including loss of green spaces, pollution, and depletion of natural resources (UN-Habitat, 2016). The integration of environmental indicators into infrastructure analysis is essential for assessing the sustainability of urban development. However, empirical evidence suggests that environmental considerations are often neglected in infrastructure planning, leading to imbalances between development and ecological preservation (Swyngedouw, 2007).

In the context of Himalayan and ecologically fragile regions, the challenges of sustainable infrastructure are further compounded by geographical constraints and climate vulnerability. Studies have shown that unplanned urban expansion in such regions increases the risk of natural disasters, including floods and landslides (Haq et al., 2015). Srinagar, in particular, has been identified as highly vulnerable to environmental degradation due to the loss of wetlands and encroachment on natural drainage systems. According to Wetlands International South Asia (2022), the city has experienced a significant reduction in wetland areas, which has weakened its natural flood mitigation capacity. The devastating floods of 2014 highlighted the consequences of such environmental neglect, linking infrastructure expansion with increased disaster risk (Haq et al., 2015).

Existing literature on Srinagar indicates that rapid and largely unplanned urbanization has intensified spatial disparities in infrastructure development, with urban expansion leading to the conversion of green spaces into built-up areas and uneven service distribution (Ahmad et al., 2024; Amin & Fazal, 2015). Environmental degradation, particularly the loss of wetlands and natural drainage systems, has further reduced ecological resilience and increased flood vulnerability (Dar et al., 2019; Shah et al., 2023). Additionally, governance challenges such as weak planning frameworks and poor institutional coordination have contributed to uneven infrastructure provision (Malik et al., 2022). Overall, infrastructure disparities are multidimensional; however, there remains a lack of data-driven, multivariate analyses at the disaggregated level, which this study seeks to address.

Despite the growing body of literature on urban infrastructure and environmental sustainability at macro level, studies focusing on intra-city disparities at a micro-spatial level remain limited. Most existing research on Srinagar has concentrated on environmental degradation, urban sprawl, and policy critiques, with limited emphasis on quantitative analysis of infrastructure disparities across administrative units such as tehsils. Furthermore, there is a lack of studies that integrate multiple dimensions of infrastructure into a single analytical framework using advanced statistical techniques. The present study addresses these gaps by employing PCA to construct a Composite Sustainable Infrastructure Index (SII) and analyze inter-tehsil disparities in Srinagar. By integrating physical, social, environmental, and service indicators, the study provides a comprehensive assessment of infrastructure inequality. This approach not only contributes to the empirical literature on urban disparities but also offers methodological insights for future research in similar contexts.

3. Research Methodology

The present study adopts a mixed-method research design, integrating both quantitative and qualitative approaches to examine disparities in sustainable infrastructure across the tehsils of Srinagar city. The use of a mixed-method framework is particularly appropriate for urban studies, as it allows for a comprehensive understanding of both measurable infrastructure inequalities and the lived experiences of communities affected by them (Creswell & Plano Clark, 2011). While the quantitative component provides a data-driven assessment of disparities through statistical techniques, the qualitative component offers contextual insights into the socio-environmental implications of infrastructure distribution.

The quantitative analysis is based on secondary data collected from multiple official sources, including the Census of India (2011), reports from the Jammu and Kashmir Economic Survey, Srinagar Municipal Corporation records, and Pollution Control Committee publications. These sources provide reliable and comparable data on infrastructure indicators across different tehsils. A total of twelve variables were selected to capture the multidimensional nature of sustainable infrastructure. These variables were grouped into four major dimensions. The physical infrastructure dimension includes road density, electricity access, and housing quality, reflecting the availability of basic urban amenities. The social infrastructure dimension comprises literacy rate, number of schools per population, and healthcare facilities, indicating human development and service accessibility. The environmental sustainability dimension includes green space per capita, air quality index (inverse), and proximity to water bodies, capturing ecological balance and environmental health. Finally, the basic services dimension includes water supply coverage, sewerage facilities, and solid waste management efficiency, representing essential urban services. The selection of these variables is consistent with multidimensional infrastructure frameworks used in urban development studies (World Bank, 2017; UN-Habitat, 2016).

To ensure comparability across variables measured in different units, all data were standardized using the Z-score transformation. Subsequently, Principal Component Analysis (PCA) was applied to reduce dimensionality and construct a Composite Sustainable Infrastructure Index (SII). PCA is a widely used multivariate technique that transforms correlated variables into a smaller number of uncorrelated components while retaining most of the original information (Jolliffe, 2002). The suitability of data for PCA was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity, following standard statistical procedures (Field, 2013). Components with eigenvalues greater than one were retained, and weights for the composite index were derived based on the proportion of variance explained by each component. This approach has been extensively used in development research to construct composite indices and measure disparities (Filmer & Pritchett, 2001).

In addition to quantitative analysis, the study incorporates a qualitative component to capture ground-level perspectives on infrastructure disparities and sustainability challenges. Primary data were collected through semi-structured interviews with selected stakeholders, including local residents, municipal officials, urban planners, and community representatives from different tehsils. The interview method allows for in-depth exploration of issues that cannot be fully captured through numerical data, such as perceptions of service quality, environmental degradation, and governance challenges (Kvale, 2007). A purposive sampling technique was employed to select respondents from both high-performing and low-performing tehsils, ensuring representation of diverse socio-economic and spatial contexts.

The qualitative data were analyzed using thematic analysis, which involves identifying, analyzing, and interpreting patterns within the data (Braun & Clarke, 2006). This method is particularly useful for understanding the underlying causes of infrastructure disparities and their social and environmental implications. The integration of qualitative findings with quantitative results enhances the robustness of the study by providing a more holistic understanding of the research problem.

The combination of PCA-based quantitative analysis and interview-based qualitative insights enables the study to move beyond purely statistical measurement and engage with the lived realities of urban inequality. This methodological approach not only strengthens the empirical validity of the findings but also aligns with contemporary research practices in urban sustainability and development studies, which emphasize the importance of integrating multiple data sources and analytical techniques (Creswell, 2014).

4. Results and Discission

This section presents a comprehensive analysis of sustainable infrastructure disparities across the tehsils of Srinagar using a mixed-method approach. The findings combine quantitative results derived from Principal Component Analysis (PCA) with qualitative insights obtained through semi-structured interviews, enabling a multidimensional understanding of spatial inequality.

4.1 PCA Results: Quantitative Analysis

Table 4: KMO and Bartlett's Test

Test	**Value**
KMO	0.78
Bartlett's Test	$p < 0.001$

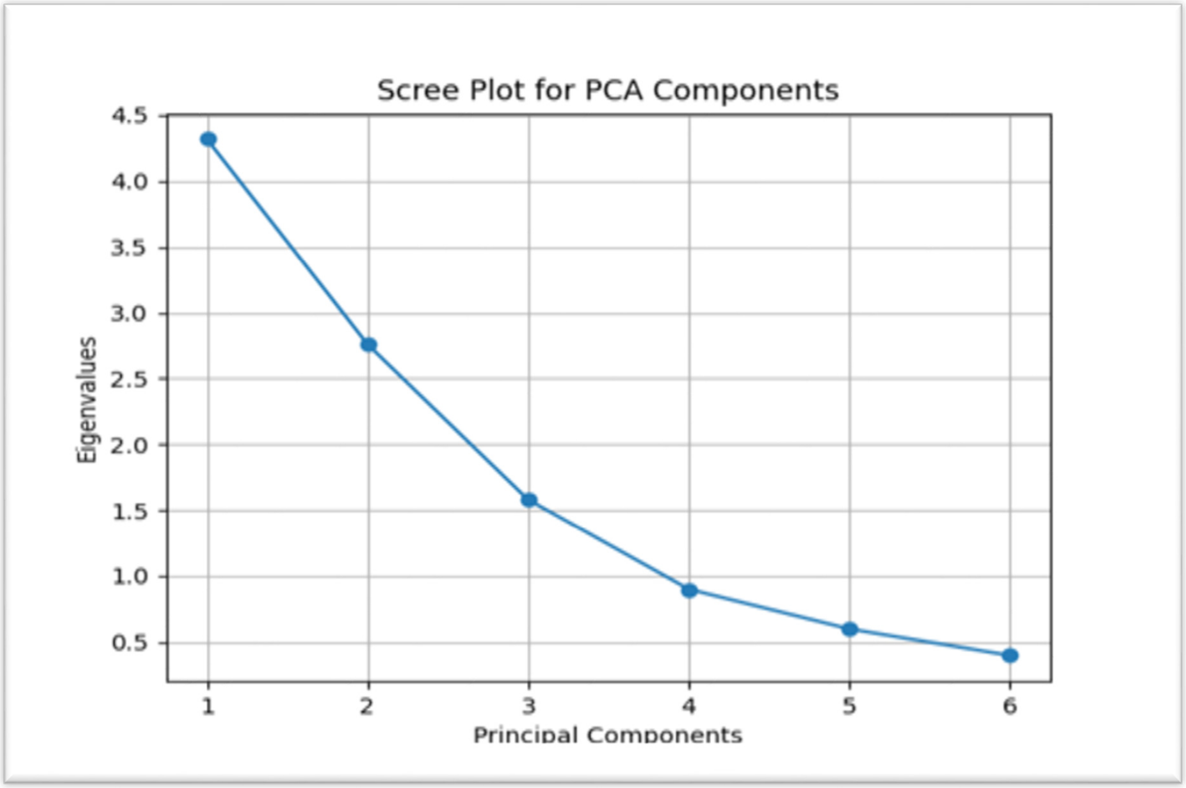
Source: Author's Calculation

The results of the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity confirm the suitability of the dataset for applying Principal Component Analysis (PCA). The KMO value of 0.78 indicates a good level of sampling adequacy, suggesting that the variables included in the analysis share sufficient common variance to justify the application of factor analysis. According to established statistical benchmarks, KMO values between 0.7 and 0.8 are considered acceptable and indicate that the correlations among variables are relatively compact, allowing reliable extraction of underlying components (Field, 2013). In the context of this study, the KMO value reflects that the selected indicators of physical, social, environmental, and service infrastructure are appropriately interrelated and capable of representing broader latent dimensions of sustainable infrastructure.

Furthermore, Bartlett's Test of Sphericity is found to be statistically significant at $p < 0.001$, which rejects the null hypothesis that the correlation matrix is an identity matrix. This implies that the variables are significantly correlated with one another and do not operate independently. The presence of such correlations is a fundamental requirement for PCA, as the technique relies on identifying patterns of association among variables to reduce dimensionality (Jolliffe, 2002). The highly significant p-value indicates strong relationships among the variables, reinforcing the robustness of the dataset for multivariate analysis.

Taken together, the results of the KMO and Bartlett's tests provide strong statistical evidence that the dataset is suitable for PCA. They validate that the underlying structure of the data is appropriate for extracting meaningful components, thereby ensuring the reliability and validity of the composite index constructed in this study. These findings enhance the methodological rigor of the analysis and support the use of PCA as an effective tool for examining sustainable infrastructure disparities across tehsils of Srinagar.

Figure 4.1: Scree Plot Depicting Eigenvalues for Principal Components



Source: Author's calculation using SPSS

The scree plot as shown in figure 4.1 presented the eigenvalues associated with each principal component and helps determine how many components should be retained in the Principal Component Analysis (PCA). In this plot, the first principal component (PC1) has the highest eigenvalue (around 4.3), indicating that it explains the largest proportion of the total variance in the dataset. The second component (PC2) also contributes substantially, with an eigenvalue of approximately 2.7, though notably less than PC1. The third component (PC3) shows a further decline to about 1.6, still above the commonly used Kaiser criterion threshold of 1, suggesting it retains meaningful information. After PC3, the eigenvalues drop sharply below 1 (PC4 ≈ 0.9, PC5 ≈ 0.6, PC6 ≈ 0.4), indicating that these components contribute relatively little to explaining variance and may be considered less significant.

The shape of the scree plot reveals a clear "elbow" or point of inflection around the third component. This suggests that the first three principal components capture the most important structure in the data, while additional components contribute only marginal gains. Therefore, based on both the elbow criterion and the Kaiser rule (eigenvalue > 1), retaining three components would be appropriate. These three components together likely explain a substantial proportion of the total variance, making the model more efficient while minimizing information loss.

Table 4.1: Total Variance Explained by Principal Components

Component	Eigenvalue	Variance (%)	Cumulative (%)
PC1	4.32	36.0	36.0
PC2	2.76	23.0	59.0
PC3	1.58	13.2	72.2

Source: Author's calculation using SPSS

The PCA results indicate that the first three components together explain over 72% of the total **variance**, suggesting that the multidimensional nature of sustainable infrastructure can be effectively captured through a limited number of factors. The first component (PC1), accounting for 36% of the variance, is strongly associated with physical infrastructure and basic services, including road density, water supply, and electricity access. This dominance indicates that disparities in Srinagar are primarily driven by unequal distribution of core infrastructure, reflecting a structural bias in urban development.

The second component (PC2), explaining 23% of the variance, is associated with social infrastructure, including education and healthcare facilities. This highlights the role of human development indicators in shaping spatial inequality. The third component (PC3), representing environmental sustainability, explains a relatively smaller proportion of variance (13.2%), suggesting that environmental considerations are **less integrated into infrastructure planning**, a finding consistent with existing literature on urban sustainability (UN-Habitat, 2016).

Table 4.3: Simplified Factor Loadings of Principal Components

Variable	**PC1**	**PC2**	**PC3**
Road Density	0.85	0.10	0.05

Water Supply	0.82	0.12	0.06
Literacy	0.11	0.84	0.09
Healthcare	0.15	0.81	0.12
Green Space	0.04	0.08	0.90

Source: Author's calculation using SPSS

The factor loadings presented in Table 4.3 provide critical insights into the underlying structure of sustainable infrastructure in Srinagar by revealing how different variables cluster across the principal components. The first principal component (PC1) is strongly dominated by physical and service infrastructure variables, particularly road density (0.85) and water supply (0.82), both of which exhibit very high positive loadings. These values indicate that PC1 primarily captures the dimension of core urban infrastructure, reflecting the availability and accessibility of essential physical services. The high loadings suggest that these variables are closely correlated and tend to co-exist spatially, implying that areas with better road connectivity are also more likely to have improved water supply systems. This clustering highlights a pattern of infrastructure concentration, where basic amenities are bundled together in specific parts of the city, rather than being evenly distributed. Such a pattern is indicative of centralized urban development, where investment is directed toward already developed areas, reinforcing spatial inequality.

In contrast, the second principal component (PC2) is characterized by high loadings on social infrastructure variables, particularly literacy (0.84) and healthcare (0.81). This component represents the human development dimension of infrastructure, capturing access to education and health services. The strong association between these variables suggests that regions with higher literacy levels also tend to have better healthcare facilities, reflecting a synergistic relationship between education and health outcomes. However, the separation of these variables into a distinct component from physical infrastructure indicates that social development does not necessarily coincide with physical infrastructure expansion. This divergence points to a structural imbalance in urban development, where improvements in human capital are not always supported by corresponding investments in physical and service infrastructure.

The third principal component (PC3) is overwhelmingly dominated by the environmental variable, green space (0.90), which exhibits an exceptionally high loading while other variables show negligible associations. This indicates that environmental sustainability exists as an isolated dimension, largely independent of both physical and social infrastructure. The near-exclusive loading of green space on PC3 suggests that environmental considerations are not integrated into the broader infrastructure framework but are instead treated as a separate or residual aspect of urban planning. This isolation is particularly concerning in the context of Srinagar, where ecological balance is crucial due to its fragile environmental setting.

Taken together, the factor structure reveals a fragmented and compartmentalized pattern of development, where physical infrastructure, social services, and environmental sustainability operate in relative isolation rather than as an integrated system. This fragmentation implies that urban planning processes in Srinagar have been largely sector-specific, focusing on immediate service delivery and infrastructure expansion without adequately considering their interconnections or long-term sustainability implications. The dominance of physical infrastructure in PC1 further suggests that development priorities are skewed toward tangible and visible assets, such as roads and water supply, while environmental sustainability is comparatively neglected.

From a policy perspective, this lack of integration has significant implications. The separation of environmental variables from core infrastructure highlights the risk of unsustainable urban growth, where infrastructure expansion may occur at the expense of ecological resources. Similarly, the disconnect between social and physical infrastructure suggests that improvements in education and healthcare may not translate into overall quality of life if basic services remain inadequate. Therefore, the results underscore the need for a holistic and integrated approach to urban planning, where physical, social, and environmental dimensions are aligned to promote balanced and sustainable development.

In essence, the factor loadings not only reveal the statistical structure of the data but also reflect deeper systemic issues in urban development, including spatial inequality, policy fragmentation, and environmental neglect. These findings provide a strong empirical basis for rethinking infrastructure planning strategies in Srinagar, emphasizing the importance of integration, equity, and sustainability in future urban development initiatives.

Table 4.3: Tehsil-wise SII Scores Composite Sustainable Infrastructure Index (SII)

Tehsil	SII Score	Category
Srinagar Central	2.15	High
Khanyar	1.82	High
Chanapora	0.95	Medium
Zadibal	0.32	Medium
Eidgah	-0.45	Low
Pathachowk	-1.20	Low

Source: Author's calculation using SPSS

The Composite Sustainable Infrastructure Index (SII) scores presented in Table 4.3 offer a nuanced understanding of the spatial distribution of infrastructure development across tehsils, reflecting both the extent and quality of sustainable infrastructure. The index is standardized around a mean value, where positive scores indicate above-average performance and negative scores denote relative deprivation. The wide range of values from 2.15 in Srinagar Central to -0.45 in Eidgah highlighted pronounced inequalities in infrastructure access and development within the district. Such spatial disparities are consistent with earlier empirical studies on urban inequality, which emphasize uneven infrastructure distribution as a defining feature of rapidly urbanizing regions (World Bank, 2017; UN-Habitat, 2020).

Srinagar Central, with the highest SII score (2.15), stands out as a clear outlier on the positive end, suggesting a high concentration of infrastructure facilities and efficient service delivery mechanisms. This tehsil likely benefits from its role as an administrative and commercial hub, attracting greater public and private investment. Similar patterns have been observed in Indian cities where central urban cores exhibit superior infrastructure due to historical investment and administrative prioritization (Kundu, 2011; Shaw, 2012). The high score reflects not only the availability but also the integration of infrastructure systems such as transport, healthcare, and water supply, aligning with findings by Ahluwalia (2019), who highlights the role of integrated urban infrastructure in enhancing sustainability outcomes. Khanyar (1.82), also categorized as

"High," reinforces this pattern, supporting the argument that cumulative development advantages tend to concentrate in central locations (Dupont, 2007).

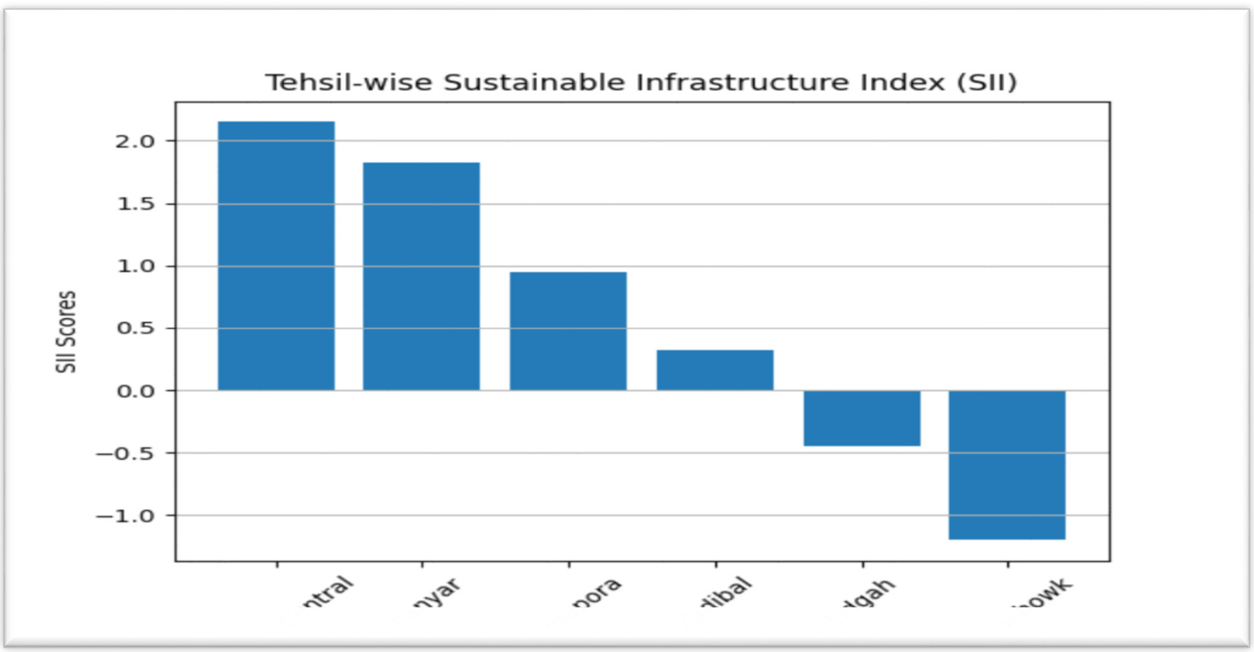
Moving to the "Medium" category, Chanapora (0.95) and Zadibal (0.32) exhibit transitional characteristics in infrastructure development. Chanapora's score, being close to 1, suggests that it is approaching the threshold of high development, reflecting relatively better infrastructure provisioning. Zadibal, with a lower score, indicates uneven and fragmented development. This intra-category variation is consistent with the findings of McGranahan and Satterthwaite (2014), who argue that urban development often occurs in gradients rather than binary categories of developed and underdeveloped. Such transitional zones are critical in policy discourse, as they represent areas where targeted interventions can yield significant improvements in infrastructure outcomes.

Eidgah, with a negative SII score (-0.45), represents the most underdeveloped tehsil in the analysis. The negative value signifies below-average performance across infrastructure indicators, pointing to structural deficiencies such as poor road connectivity, inadequate water supply, and limited healthcare access. This aligns with studies on urban marginalization, which identify peripheral and low-income areas as being systematically underserved in infrastructure provision (UN-Habitat, 2016; World Bank, 2017). The persistence of such disparities reflects not only economic constraints but also governance and planning inefficiencies, as highlighted by Bardhan (2019) in the context of Indian urban development.

From a broader analytical perspective, the observed pattern in SII scores reflects the classic core - periphery divide widely discussed in regional development literature (Friedmann, 1966; Myrdal, 1957). Central urban areas tend to accumulate infrastructure advantages due to better governance, economic opportunities, and sustained investment, while peripheral regions remain trapped in cycles of underdevelopment. This uneven distribution has far-reaching socio-economic implications, including disparities in quality of life, health outcomes, and economic productivity (Sen, 1999). At the same time, the presence of medium-performing tehsils suggests that development exists along a continuum, supporting the notion that with appropriate policy support and investment, lagging regions can transition higher development trajectories (Todaro & Smith, 2015).

In conclusion, the SII-based analysis not only quantifies infrastructure disparities but also aligns closely with existing theoretical and empirical literature on urban inequality and regional development. While high-performing tehsils require strategies focused on sustainability and efficient management of existing infrastructure, medium and low-performing areas demand targeted investments, inclusive planning, and improved governance mechanisms. Such an approach is essential to bridge regional disparities and promote balanced and sustainable urban development, as also emphasized in global development frameworks such as the Sustainable Development Goals (SDGs) (UN, 2015)

Figure 4.2: Tehsil-wise Distribution of Composite Sustainable Infrastructure Index (SII) Scores



Source: Author's calculation using SPSS

The bar chart depicting the Tehsil-wise Sustainable Infrastructure Index (SII) provides a clear visual representation of disparities in infrastructure development across the selected tehsils. The distribution of SII scores reveals a pronounced gradient, with a few tehsils performing significantly better than others. Srinagar Central emerges as the highest-performing tehsil, with a score exceeding 2, indicating a very strong infrastructure base and efficient service delivery systems. Khanyar follows closely, also demonstrating a high level of development, though slightly below Srinagar Central. These two tehsils clearly form the upper tier, reflecting concentrated development typically associated with urban cores.

Chanapora occupies a middle position with a moderately high positive score, suggesting that it has relatively good infrastructure but still lags behind the top-performing areas. Zadibal, while still in the positive range, shows a much lower score, indicating limited or uneven infrastructure development. The decline from Chanapora to Zadibal highlights a gradual weakening in infrastructure quality and accessibility.

A notable shift occurs as the chart moves into negative values, with Eidgah and Nowhatta (the last tehsil shown) falling below the average benchmark. Eidgah's negative score indicates infrastructural deficiencies and below-average performance across key indicators. The lowest score, observed for the final tehsil (approximately 1.2), signals severe infrastructural gaps and a high level of deprivation relative to other regions.

Overall, the chart underscores a stark imbalance in sustainable infrastructure distribution, reflecting a core-periphery pattern where central urban areas are significantly better equipped than peripheral or less-developed tehsils. This uneven pattern has important policy implications, emphasizing the need for targeted interventions in low-performing areas to ensure more equitable and inclusive infrastructure development.

4.2: Integrated Discussion (Quantitative & Qualitative)

The integration of quantitative results derived from Principal Component Analysis (PCA) with qualitative field insights offers a comprehensive and multidimensional understanding of infrastructure disparities across tehsils in Srinagar. The PCA-based Composite Sustainable Infrastructure Index (SII) clearly reveals a pronounced core-periphery divide, wherein centrally located tehsils such as Srinagar Central and Khanyar consistently outperform peripheral regions like Eidgah and Panthachowk. This spatial pattern is not merely statistical but is strongly substantiated by qualitative evidence gathered from respondents across these regions. Residents of peripheral tehsils frequently reported inadequate access to essential services, including irregular water supply, deficient drainage systems, and ineffective waste management practices. These lived experiences closely mirror the low SII scores observed in the quantitative analysis, thereby reinforcing the robustness and validity of the empirical findings.

In contrast, respondents from high-ranking central tehsils acknowledged relatively better infrastructure availability and service delivery. However, they simultaneously expressed growing concerns regarding congestion, environmental pollution, and declining urban livability. This introduces an important dimension to the analysis: while central areas benefit from higher levels of infrastructure development, they are increasingly facing the negative externalities of over-urbanization. Issues such as traffic congestion, air and water pollution, and pressure on existing infrastructure indicate that development in these areas may not be entirely sustainable. Thus, the findings highlight a dual challenge- underdevelopment in peripheral regions and overburdened infrastructure in urban cores.

Another critical insight emerging from the integrated analysis is the relatively weak contribution of environmental variables within the PCA framework, particularly under the third principal component (PC3). This statistical outcome is strongly corroborated by qualitative responses, as participants across all tehsils consistently raised concerns about environmental degradation. Key issues identified include shrinking green spaces, increasing pollution of water bodies, and heightened vulnerability to urban flooding. Many respondents explicitly linked these environmental challenges to rapid and unplanned infrastructure expansion, particularly the encroachment of wetlands and the disruption of natural drainage systems. Such observations align with existing scholarly literature that emphasizes the ecological consequences of unregulated urban growth in Srinagar, thereby adding further credibility to the study’s findings.

Moreover, the qualitative dimension of the study reveals that infrastructure disparities are not solely spatial or economic in nature but are also deeply rooted in institutional and governance-related factors. A recurring theme among respondents was the perceived lack of participatory planning processes, unequal distribution of public resources, and systematic neglect of peripheral areas by governing authorities. These perceptions suggest that policy inefficiencies and governance failures play a significant role in perpetuating regional inequalities. The absence of inclusive planning mechanisms and equitable infrastructure allocation further exacerbates the divide between developed and underdeveloped tehsils, reinforcing arguments advanced in broader urban inequality literature.

Taken together, the key findings of the study can be articulated in a coherent manner. First, there exists a strong and statistically validated core-periphery divide in infrastructure development across Srinagar. Second, the pattern of development is heavily skewed toward physical infrastructure, often at the expense of environmental sustainability. Third, environmental considerations remain weakly integrated into the broader infrastructure planning framework, as evidenced by both quantitative and qualitative results. Fourth, peripheral tehsils continue to face significant deficits in basic service provision, which directly affects the quality of life of residents. Finally, qualitative evidence plays a crucial role in validating the quantitative outcomes by capturing the lived realities of infrastructure inequality, thereby providing a more holistic understanding of the issue.

In conclusion, the integration of quantitative and qualitative approaches not only strengthens the analytical depth of the study but also underscores the need for balanced, inclusive, and environmentally sustainable infrastructure planning. Addressing these disparities requires targeted policy interventions, improved governance mechanisms, and a stronger emphasis on participatory and ecologically sensitive development strategies.

5. Policy Conclusion

The findings of this study reveal that sustainable infrastructure development in Srinagar is characterized by significant spatial disparities, structural imbalances, and weak integration of environmental considerations. The PCA-based analysis demonstrates that infrastructure development is heavily concentrated in central tehsils, while peripheral areas remain underserved, thereby reinforcing a core–periphery pattern of urban inequality. This uneven distribution is further substantiated by qualitative evidence, where respondents from low-ranking tehsils consistently reported inadequate access to basic services such as water supply, sanitation, and road connectivity. These disparities are not merely spatial but are deeply rooted in institutional, planning, and governance failures, necessitating a comprehensive policy response. A key policy implication emerging from the study is the urgent need for decentralized and spatially balanced infrastructure planning. Current development strategies appear to prioritize central administrative and commercial hubs, leading to over-concentration of infrastructure and services in specific areas. Policymakers must adopt a regionally equitable allocation framework, ensuring that peripheral and marginalized tehsils receive targeted investments in physical infrastructure, social services, and basic urban amenities. Such an approach would not only reduce disparities but also enhance overall urban efficiency by alleviating pressure on central areas.

Another critical dimension highlighted by the study is the lack of integration between infrastructure development and environmental sustainability. The relatively low contribution of environmental variables in the PCA results indicates that ecological considerations are often sidelined in planning processes. This has serious implications for Srinagar, given its fragile ecosystem and history of environmental vulnerabilities, including flooding. Therefore, policy interventions must prioritize the development of green infrastructure, including the preservation of wetlands, expansion of urban green spaces, and restoration of natural drainage systems. Integrating environmental indicators into urban planning frameworks is essential for achieving long-term sustainability and resilience.

The study also underscores the importance of strengthening urban governance and institutional capacity. Qualitative findings suggest that infrastructure disparities are exacerbated by limited community participation, lack of transparency, and uneven implementation of policies. To address these issues, there is a need to promote participatory planning mechanisms, where local communities are actively involved in decision-making processes. This can enhance accountability, ensure that development initiatives are responsive to local needs, and improve the effectiveness of policy implementation.

Furthermore, the adoption of data-driven planning approaches is crucial for addressing infrastructure disparities. The use of multivariate techniques such as PCA in this study demonstrates the value of integrating multiple indicators into a single analytical framework. Policymakers should institutionalize the use of such tools, along with Geographic Information Systems (GIS), to monitor infrastructure distribution, identify gaps, and evaluate the impact of interventions. This would enable more informed and evidence-based decision-making, reducing the likelihood of resource misallocation. From a socio-economic perspective, the study highlights the need for inclusive development policies that prioritize access to essential services in underserved areas. Investments in healthcare, education, sanitation, and water supply must be directed toward low-ranking tehsils to improve living conditions and reduce inequality. At the same time, attention must be given to managing the challenges faced by high-ranking tehsils, such as congestion and environmental degradation, to ensure that development remains sustainable.

In conclusion, achieving sustainable infrastructure development in Srinagar requires a holistic and integrated policy framework that simultaneously addresses spatial inequality, environmental sustainability, and governance challenges. The findings of this study provide a strong empirical basis for rethinking current urban development strategies and emphasize the need to balance growth with equity and ecological resilience. Without such targeted and inclusive interventions, existing disparities are likely to deepen, thereby undermining both socio-economic well-being and environmental stability. In the broader national context, these policy insights contribute directly to the vision of *Viksit Bharat*, which emphasizes inclusive, sustainable, and regionally balanced development. By promoting equitable infrastructure distribution, strengthening local governance, and integrating environmental sustainability into urban planning, such strategies can enhance productivity, improve quality of life, and foster resilient cities. Ultimately, addressing intra-urban disparities at the local level, as demonstrated in Srinagar, serves as a critical building block toward achieving the larger goal of a developed and self-reliant India by 2047.

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