Spatial analysis of the infrastructural status of Kargil district, Ladakh

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Abstract- Infrastructure development plays a critical role in improving livelihoods and reducing regional disparities, yet its distribution remains highly uneven in high altitude Himalayan regions. This study assesses village level infrastructure development in Kargil district of Ladakh using a composite infrastructure index based on secondary data from census records and government sources. Multiple physical, social, and economic infrastructure indicators were normalized using the min max method and integrated at the village scale.

The results reveal marked spatial inequalities and a clear core periphery pattern. Kargil and Sanku sub districts emerge as infrastructure cores with relatively better access to services and connectivity. Drass shows moderate but uneven development, while Shaker Chiktan and Zanskar remain the most infrastructure deficient due to remoteness, difficult terrain, and harsh climatic conditions. The study highlights persistent intra sub district disparities and shows that improved connectivity alone has not ensured balanced development. The findings emphasize the need for spatially targeted and context specific infrastructure planning to promote inclusive and sustainable development in high altitude regions.

Keywords- Infrastructure development, Composite infrastructure index, Spatial inequality, High altitude region, Kargil district, Ladakh.

I.INTRODUCTION

Globally, infrastructure development is recognised as a central pillar of economic growth, social welfare, and regional stability. Investment in transport, energy, water supply, health, and education systems plays a crucial role in reducing regional disparities and improving access to essential services, especially in remote and environmentally sensitive areas (World Bank, 2019; UNDP, 2020). In mountain regions, however, such development faces serious limitations. Steep terrain, harsh climatic conditions, frequent natural hazards, and high construction and maintenance costs restrict infrastructure expansion and often lead to uneven service delivery. These constraints increase the exposure of local communities to socio-economic and environmental risks (Messerli & Ives, 1997; Dame et al., 2019). In this context, the development of rural India remains vital for achieving sustainable and inclusive growth, as it directly influences livelihood security, regional equity, and long-term resilience. Rural areas account for about 909 million people (65 per cent of the population), nearly 70 per cent of the labour force, around 35 per cent of FMCG demand, and contribute nearly 49.5 per cent of national GDP (Chand et al., 2017) Despite policy efforts, agriculture remains the dominant rural occupation, and agricultural incomes stagnated during 2013–2018 (NABARD, 2018

Infrastructure development is central to achieving the Sustainable Development Goals, particularly those related to poverty reduction, livelihoods, income, health, education, water, and sanitation (Thacker et al., 2019). Both physical and institutional infrastructure, including irrigation, electricity, roads, markets, credit institutions, healthcare, education, and agricultural research and extension, plays a decisive role in raising agricultural productivity, expanding non-farm employment, and supporting broader economic development (Edeme et al., 2020). A large body of empirical work shows that infrastructure investment has a strong and consistent influence on agricultural performance. Irrigation facilities and a reliable power supply increase cropping intensity, promote more efficient land use, support the adoption of modern inputs, and lead to higher agricultural output (Dhawan, 1988; Shah, 1993; Vaidyanathan et al., 1994; Narayanamoorthy and Deshpande, 2005; Ghosh, 2017; Manjunath and Kannan, 2017). Access to electricity also improves household livelihoods and overall quality of life (Sarkodie and Adams, 2020). Similarly, better rural road connectivity enhances mobility, lowers transaction costs, strengthens supply chains, and improves price realisation, thereby raising farm incomes (Ahmed and Donovan, 1992; ESCAP, 2000; van de Walle, 2002; Ghosh, 2017; Kumar, 2020; Kamaludin and Qibthiyyah, 2022). The benefits of rural infrastructure extend well beyond agriculture. Improved connectivity and service provision enhance access to healthcare, education, financial services, and livestock-based livelihoods, contributing to wider social and economic gains (Ghosh, 2017; Narayanamoorthy et al., 2022). Market related infrastructure further improves marketing efficiency and reduces post-harvest losses (Sekhon et al., 2022). When infrastructure development is complemented by investments in human resources, it becomes a powerful driver of poverty reduction, employment generation, and inclusive rural transformation (Chand et al., 2017).

In India, infrastructure expansion has long been a central component of development policy aimed at strengthening connectivity and regional integration. Despite this emphasis, the Himalayan region continues to lag behind the plains. Seasonal isolation, hazard prone terrain, and logistical difficulties constrain infrastructure provision, particularly in high altitude and border districts (Government of India, 2018; Bhat, 2023). As a result, infrastructure development in the Indian Himalayas remains closely tied to livelihood security, accessibility to basic services, and disaster risk reduction.

Within this broader national setting, the Union Territory of Ladakh stands out as one of the most infrastructure constrained regions in the country. Located in the Trans Himalayan zone, Ladakh is marked by extreme cold conditions, sparse population, very low precipitation, and fragile ecosystems. Historically, infrastructure development in the region has been shaped largely by strategic and administrative priorities, with a strong focus on road connectivity. Although recent investments in transport and urban infrastructure have improved regional integration, large disparities remain in access to healthcare, education, water supply, and energy services, especially in rural and remote settlements (Dame et al., 2019; Bhat, 2023).

These challenges are clearly visible in Kargil district, where difficult terrain, long winters, and dependence on a few key road corridors continue to shape development pathways. While road expansion has improved urban growth, administrative functions, and market access, it has also placed growing pressure on land, public services, and natural resources (Hussain, 2023). Rural areas remain particularly disadvantaged, with limited access to transport, education, and healthcare reinforcing multidimensional poverty and livelihood insecurity (Banoo & Mishra, 2025). At the same time, infrastructure expansion and the broader process of modernization have increased environmental risks through unplanned settlement growth in hazard prone areas, while also influencing social and cultural change, including shifts in indigenous practices and women’s roles. Together, these processes illustrate how infrastructure development in Kargil is closely intertwined with environmental vulnerability and socio-cultural transformation (Bhat, 2023; Kumari & Batool, 2024).

Together, these dynamics underline the need for climate sensitive, spatially balanced, and sustainability-oriented infrastructure planning. They also point to the importance of a systematic assessment of infrastructure conditions to identify development gaps, patterns of vulnerability, and pathways for building long term resilience in this high-altitude Himalayan region.

II. STUDY AREA

Kargil district, located in the northernmost part of India within the Union Territory of Ladakh, is a high-altitude region forming part of the Trans-Himalayan belt. Geographically, the district lies between latitudes 30°–35° N and longitudes 75°–77° E, covering an area of approximately 14,036 km² (LAHDC Kargil, 2021). The landscape is predominantly rugged and mountainous, shaped by the Karakoram, Ladakh, and Zanskar ranges. As per the 2011 Census, the district supports a sparse population of nearly 150,000 people, and its landlocked setting results in limited connectivity with the rest of India (Habibullah et al., 2025).

Road connectivity to Kargil is primarily maintained through Jammu and Kashmir, with a single major arterial route linking the district to the national road network (Akbar et al., 2023). Seasonal mountain passes such as Zojila (3,567 m) and Fotulla (4,192 m) serve as critical corridors, connecting Kargil to the Kashmir Valley and Leh district. The district's highest elevations include the Namikala and Penzila passes. Hydrologically, Kargil is drained by major rivers such as the Suru, Drass, and Zanskar, all of which form part of the upper Indus tributary system (LAHDC Kargil, 2021). Lying largely above 2,500 m above mean sea level the region is characterized by barren landscapes, steep and narrow valleys, and sparse vegetation cover, reflecting the harsh climatic and topographic conditions (Statistical Handbook, 2021).

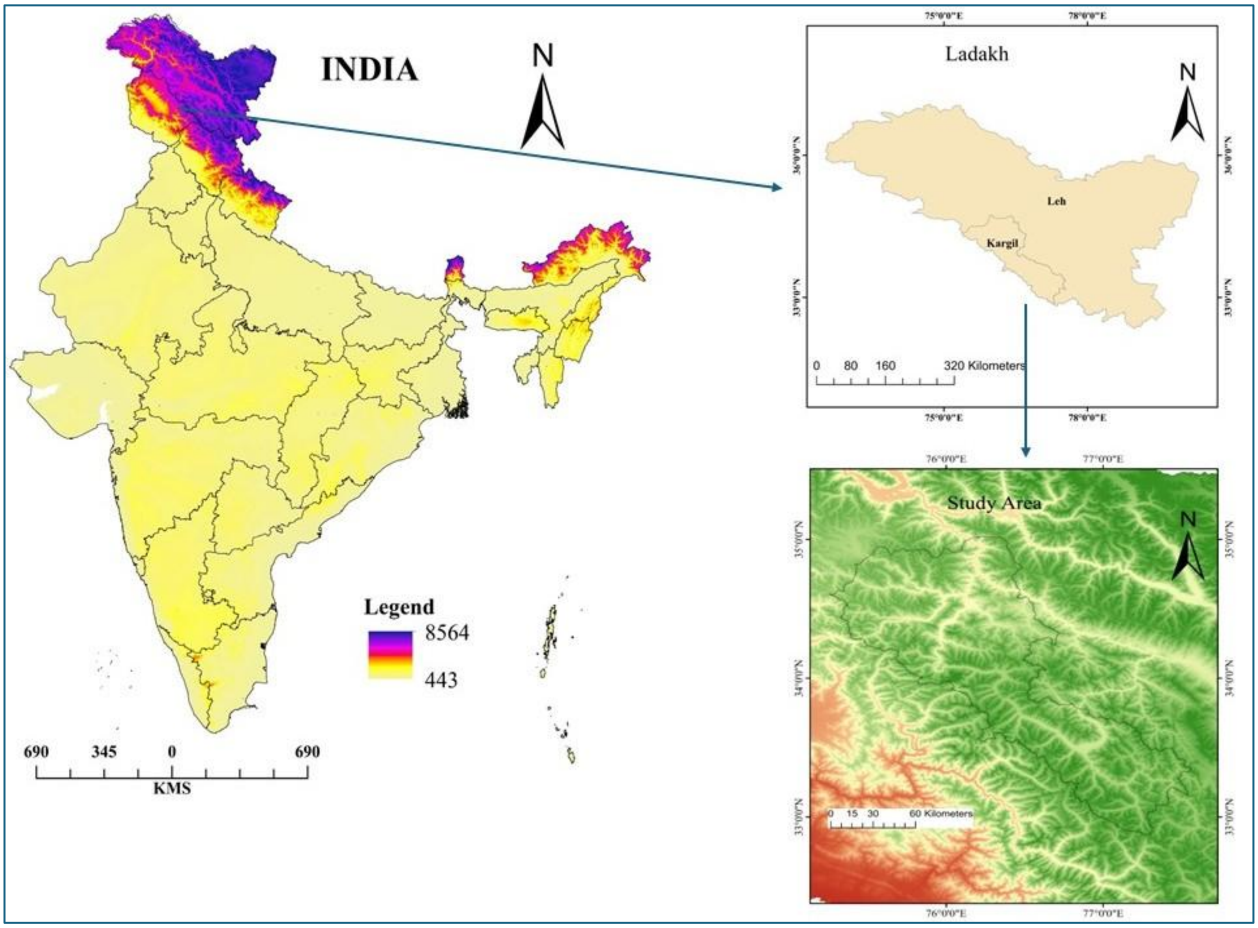

Fig.1 Study Area

III. DATA SOURCES AND METHODOLOGY

The present study is based on secondary data collected from multiple government and institutional sources to assess village-level infrastructure conditions in Kargil district. The analysis was conducted at the village scale using a composite index approach, which allows for the integration of multiple infrastructure-related indicators into a single, comparable measure.

Secondary data were compiled from official census records, district statistical handbooks, line department reports, and other authenticated government publications. These datasets provide consistent and reliable village-wise information on basic infrastructure and service availability across the district.

3.1. Selection of Infrastructure Indicators

Infrastructure indicators were selected from the selection was guided by conceptual relevance and data availability, focusing on variables that directly represent physical, social, and economic infrastructure at the village level.

Table 1.1: Binary Infrastructure Indicators Used in the Study

Category	Indicator Description	Measurement
Watershed and Water Resources	Participation in watershed development projects	1 = Present, 0 = Absent
	Availability of community rainwater harvesting systems	1 = Present, 0 = Absent
	Presence of ponds, dams, or check dams	1 = Present, 0 = Absent
Transport and Connectivity	Connectivity to all-weather roads	1 = Present, 0 = Absent
	Availability of internal pucca roads (cement concrete/brick)	1 = Present, 0 = Absent
	Availability of public transport facilities	1 = Present, 0 = Absent
	Presence of a railway station	1 = Present, 0 = Absent
Energy Infrastructure	Availability of electricity for domestic use	1 = Present, 0 = Absent
	Electricity supply to MSME units	1 = Present, 0 = Absent
	Use of solar or wind energy for household electrification	1 = Present, 0 = Absent
Financial and Communication Infrastructure	Presence of banks	1 = Present, 0 = Absent
	Availability of ATMs	1 = Present, 0 = Absent
	Presence of post offices/sub-post offices	1 = Present, 0 = Absent
	Availability of internet or broadband facilities	1 = Present, 0 = Absent
Educational Infrastructure	Availability of primary schools	1 = Present, 0 = Absent
	Availability of middle schools	1 = Present, 0 = Absent
	Availability of high schools	1 = Present, 0 = Absent
	Availability of higher secondary/senior secondary schools	1 = Present, 0 = Absent
	Availability of degree colleges	1 = Present, 0 = Absent
Health and Social Infrastructure	Availability of veterinary clinics/hospitals	1 = Present, 0 = Absent
	Presence of sub-centres, PHCs, or CHCs	1 = Present, 0 = Absent
	Availability of Anganwadi centres	1 = Present, 0 = Absent
	Provision of early childhood education through Anganwadis	1 = Present, 0 = Absent
	Availability of mother and child health facilities	1 = Present, 0 = Absent

Table 1.2: Quantitative Infrastructure-Related Indicators Used in the Study

Category	Indicator Description	Unit of Measurement
Demographic Context	Total population	Number
	Total number of households	Number
Irrigation and Housing	Number of farmers using drip/sprinkler irrigation	Number
	Households sanctioned/completed under PMAY	Number
Energy and Electrification	Households electrified using solar/wind energy	Number
	Households covered under Saubhagya scheme	Number
	Households using clean cooking fuel (LPG/biogas)	Number
Financial Inclusion and Welfare	Households with Jan Dhan bank accounts	Number
	Households holding BPL ration cards	Number
Education	Children not attending school	Number
Health and Insurance	Households registered under PMJAY or state health insurance schemes	Number
Child Development (ICDS)	Children aged 0–3 years registered in Anganwadi centres	Number
	Children aged 3–6 years registered in Anganwadi centres	Number

3.2. Normalization of Indicators

To make indicators with different units and scales comparable, I used min–max normalization for each indicator across Kargil villages.

For each indicator X_j(j-th variable) and village i:

$$X_{ij}^{\text{norm}} = \frac{X_{ij} - X_j^{\min}}{X_j^{\max} - X_j^{\min}}$$

- $X_j^{\min}$: minimum value of indicator j among all Kargil villages
- $X_j^{\max}$: maximum value of indicator j among all Kargil villages
- Resulting normalized values lie between 0 and 1:
- 0 = worst performing village on that indicator (among Kargil)

- 1 = best performing village on that indicator

IV. RESULTS

4.1. Village- and Sub-District-Wise Interpretation of Infrastructure Composite Index

The village-level composite infrastructure index highlights substantial intra- and inter-sub-district disparities in infrastructure development across Kargil district. The spatial distribution of infrastructure facilities exhibits a distinct core–periphery pattern, influenced by accessibility, administrative proximity, and physiographic constraints.

4.1. 1 Drass Sub-District

In the Drass sub-district, villages such as Rambirpur (Drass), Goshan, and Pandras fall under the very high infrastructure category, reflecting comparatively better access to transport networks, basic services, and strategic connectivity along the Srinagar–Leh corridor.

The high infrastructure category includes Chokial, Kharbu, Shimsha, and Murad Bagh, which benefit from relatively improved road access and public service availability.

However, a transition towards infrastructural deficit is evident in villages such as Bambiat, Gindial, and Matayan, which fall under the medium category, indicating partial access to essential facilities. Villages including Yalboo, Jusgund, Holiyal, and Mushku record low infrastructure levels, while Thasgam represents the very low category, highlighting localized deprivation despite the sub-district's strategic importance. Overall, Drass demonstrates moderate infrastructure development with pronounced internal variability.

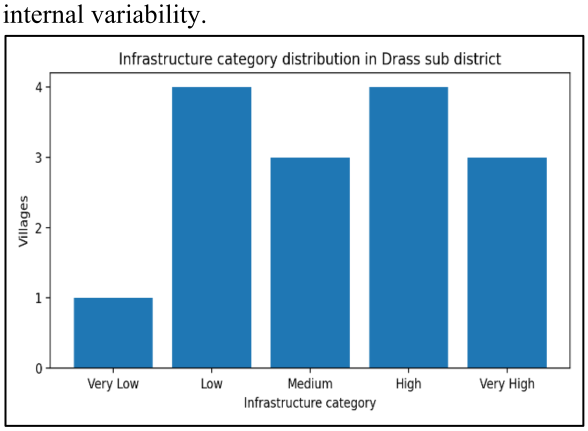

Fig. 2. Number of Villages in Drass Sub-district

4.1.2. Kargil Sub-District

Kargil sub-district emerges as the most infrastructurally developed region within the district. A large number of villages, including Kaksar, Akchamal, Apati, Chulichan, Derchiks, Hardas, Poyen, Pashkum, Shilikchey, Staktse, and Wakhade, fall under the very high infrastructure category. These villages benefit from proximity to the district headquarters, administrative institutions, healthcare facilities, educational centers, and market access.

Villages such as, Batambis, and Choskar belong to the high category, while Karkit, Minji, and Push Kum exhibit medium infrastructure levels, reflecting uneven service distribution beyond the urban core.

In contrast, Chuliskambo, Phultuks, and Safi record low infrastructure values, and remains in the very low category, indicating that infrastructural marginalization persists even within the most developed sub-district.

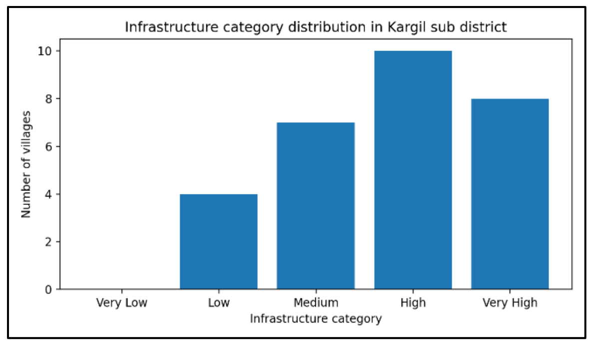

Fig.3. Number of Villages in Kargil Sub-district

4.1.3 Shaker Chiktan Sub-District

The Shaker Chiktan sub-district is characterized by overall low to moderate infrastructure development. Villages such as Chiktan, Hagnis, Samrah, Sanjak, and Shakar fall under the high infrastructure category, reflecting relatively better access to basic amenities within localized clusters.

Villages including Bodhkharbu, Yogmakharbu, and Malbekh exhibit medium infrastructure levels, whereas a large number of villages—Nunamchey, Karit, Heniskot, Karamba, Phoo, and Khalsi—are categorized as low infrastructure. The presence of several very low infrastructure villages, namely Darkiat, Lochum, Skambo, Kukste, Tacha, and Kukshoo, underscores persistent infrastructural deprivation, largely attributable to remoteness and limited institutional outreach

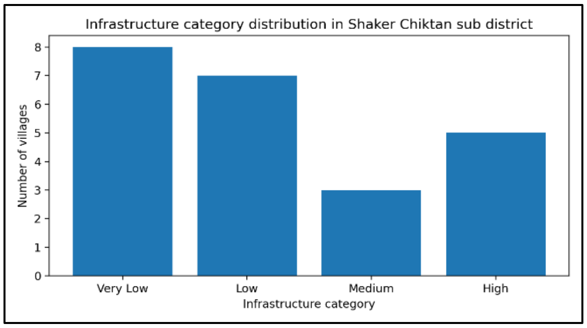

Fig. 4. Number of villages in Shakar Chikten sub district

4.1.4 Sanku Sub-District

Sanku sub-district displays a dual structure of infrastructure development. Villages such as Barsoo, Gund Mangl Pur, Saleskot, and Trespone record very high infrastructure index values, signifying their role as sub-district-level service centers.

The high category includes Kanor, Tambis, Lankarchey, Thasgam Thaine, and Khagral, while Barto, Karchey Khar, and Khandi fall under the medium category, indicating gradual infrastructural diffusion away from core villages.

However, villages like Itchoo, Stakpa, Achambur, Kochik, and Thuls Pursa are characterized by low infrastructure levels, and Shergandi, Chosker Suru, and Gyaling remain very low, highlighting pockets of deprivation within an otherwise moderately developed sub-district.

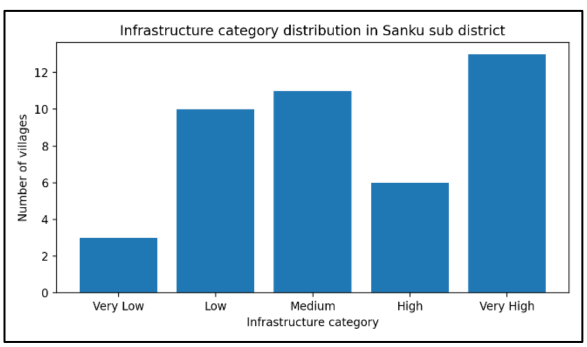

Fig.5. Number of villages in Sanku sub district

4.1.5 Zanskar Sub-District

Zanskar sub-district represents the most infrastructurally disadvantaged region in Kargil district. Although villages such as Padam, Seni, and Upti Pipiting fall under the very high category, reflecting their administrative and functional importance, infrastructural development remains highly localized.

Villages including Tangday Kumi and Zangla are classified as high infrastructure, while Ating, Phey, and Selapigai Pak exhibit medium levels. A significant proportion of villages—Karshah and Salapi Ruruk—fall under the low category, whereas Abran, Akshow, Hamiling, Remala Skyagam, and Lungnak are categorized as very low infrastructure villages. This pattern highlights the dominant influence of extreme terrain, climatic severity, and seasonal isolation on infrastructure provisioning in Zanskar.

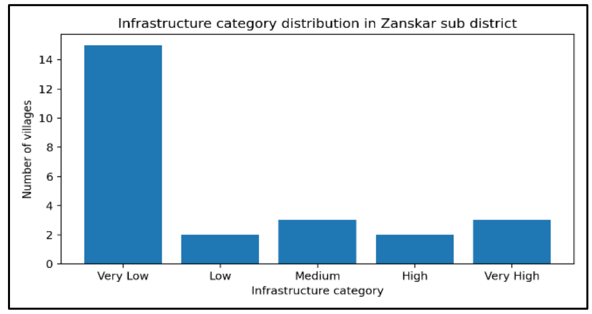

Fig. 6. Number of villages in Zanskar sub district

Overall, the infrastructure composite index highlights pronounced spatial inequalities across Kargil district (Fig. 1.1). Kargil and Sanku emerge as infrastructural cores, with composite index values ranging from 0.24 to 0.28. Drass exhibits a moderate but uneven level of development, with values between 0.18 and 0.24, while Shaker Chiktan and Zanskar constitute the peripheral, infrastructure-deficient zones, registering the lowest values (0.15–0.18). These patterns underscore the necessity for sub-district–specific and village-level infrastructure planning, particularly in high-altitude and remote areas.

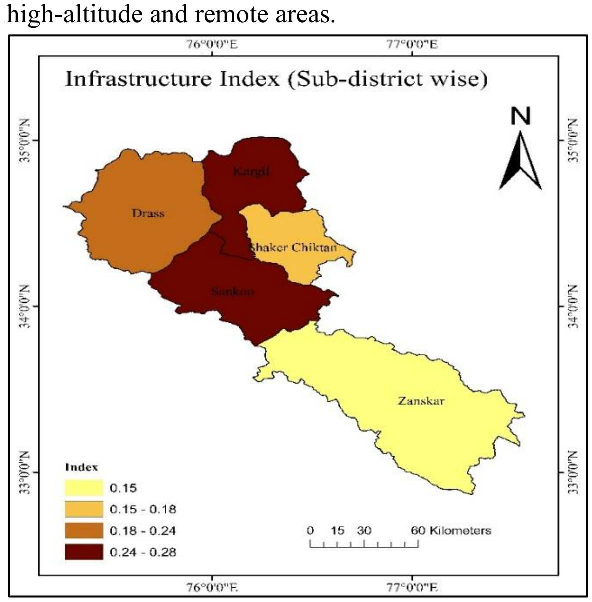

Fig 7. Infrastructure index (Subdistrict wise)

V. DISCUSSION

The results indicate a distinct core periphery pattern of infrastructure development in Kargil district, with pronounced variation across sub districts and villages. Kargil and Sanku function as the main infrastructure cores, supported by stronger administrative presence, better road connectivity, wider market access, and relatively good availability of social services. These advantages have concentrated development in and around these centres, reinforcing their dominant position within the district.

Drass occupies an intermediate position in the infrastructure hierarchy. Despite its strategic location along the Srinagar Leh corridor and the presence of several well performing villages, infrastructure conditions within the sub district vary widely. Villages range from high to very low levels of infrastructure, suggesting that strategic connectivity by itself does not guarantee balanced development. Severe climatic conditions, seasonal isolation, and local terrain constraints continue to limit the spread of services across the sub district.

In contrast, Shaker Chiktan and Zanskar emerge as the most infrastructure deficient regions. Both sub districts contain a high concentration of villages with low and very low infrastructure levels. In Zanskar, a small number of administratively important settlements display relatively better infrastructure. However, development remains highly localized, while surrounding villages continue to face persistent deprivation due to remoteness, rugged topography, and weak institutional reach.

The presence of both well developed and poorly developed villages within the same sub districts, particularly in Drass and Sanku, points to significant intra sub district inequality. Overall, the findings highlight the need for spatially differentiated and context specific infrastructure planning. Priority interventions are required in villages with low and very low infrastructure levels, especially in Drass, Shaker Chiktan, and Zanskar, to reduce regional disparities in high altitude Himalayan settings.

VI. CONCLUSION

The study reveals marked spatial inequalities in infrastructure development across Kargil district, reflecting a clear core periphery structure at both sub district and village scales. Kargil and Sanku stand out as infrastructure cores due to stronger administrative functions, better connectivity, and greater service availability. Drass occupies an intermediate position but shows substantial internal variation. Shaker Chiktan and Zanskar remain the most infrastructure constrained sub districts, shaped by remoteness, difficult terrain, and harsh climatic conditions.

Pronounced intra sub district disparities further demonstrate that infrastructure diffusion remains uneven, even within relatively better developed areas. Strategic location and connectivity alone have not ensured balanced development in high altitude regions. These findings underline the importance of spatially differentiated planning that is sensitive to local conditions. Targeted investments in low and very low infrastructure villages, particularly in Drass, Shaker Chiktan, and Zanskar, are essential for promoting more balanced and inclusive regional development.

VII. ACKNOWLEDGEMENT

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