Enhancing Resource Utilisation for Sustainable Rural Development through Smart Infrastructure Planning: A Case of Lakhtar, Surendranagar

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Abstract. India is a developing country, and all Indians are working together to make it a developed country. Growth of any country is mainly dependent upon the people living in it, and about 69% of the people of India live in rural areas. So, for the development of the country, these rural areas and these populations play a vital role. Many of the villages are still behind the rest of the world; it is because of the unavailability of some basic as well as advanced amenities. These amenities include clean drinking water, a drainage network, sewage disposal, solid waste management, electricity, energy conservation, a transportation system, education and healthcare facilities, & modern technology with good infrastructure. Lack of such facilities makes it difficult for people to live a good quality life; they are unable to connect with the rest of the world, which results in people migrating to urban areas and a lack of employment opportunities. This paper focuses on smart infrastructure planning and resource utilization to promote sustainable rural development and global skill enhancement through Lakhtar—a village in Surendranagar District, Gujarat—as a representative case. To assess the existing situation, infrastructure gaps, and available resources, a mixed methodology was used, like primary & secondary surveys, stakeholder consultations, and GIS-based spatial analysis. Mixed methods, like primary & secondary surveys, stakeholder consultations, and GIS-based spatial analysis, helped to identify gaps in the study area. Findings are lack of interconnectivity, inadequate water supply, sanitation & waste management, renewable energy integration, and skill development opportunities. Hence, the research proposes an integrated smart infrastructure framework focusing on smart & renewable energy installations, improved water and sanitation systems, enhanced connectivity, waste management, and an emphasis on the use of modern technology. The Lakhtar case study illustrates a replicable approach for similar semi-arid regions, suggesting actionable insights for planners to integrate innovation, sustainability, and skill development into rural infrastructure planning. The study also addresses that by adopting technology innovation with community participation, it can transform rural settlements into resilient, self-sufficient ecosystems. The Lakhtar case study provides a smart infrastructure model that can be followed in similar semi-arid regions. It demonstrates how to build local infrastructure while focusing on smart integration, sustainability, and skill development.

Keywords: Urban infrastructure, Civic Service delivery, ULG Spending, Physical and financial norms

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1 Introduction

1.1 Overview of Rural Development in India

Rural development means improving the living standard of the people who live in rural areas. This development is done by providing job opportunities, good education, and better infrastructure facilities. Villages, as defined by the Planning Commission of India [1], are clusters of settlements with smaller populations, lower densities, and a strong reliance on agriculture and allied activities. These settlements have a rich diversity in social, cultural, and economic structures, having similar living patterns and majorly relying on natural resources. Hence, the villages can be said to be the backbone of the nation's socio-cultural and economic framework, which highlights the need for a holistic development approach in such areas that balances traditional livelihoods with modern infrastructure and innovation.

1.2 Concept of Smart Villages

Smart Villages

The Smart Village concept in India aims at holistic rural development, inspired by Mahatma Gandhi's vision of Adarsh Gram [Ideal Village] and Swaraj [Self-Reliance]. It is adopted by national, state, and local governments. This initiative gained momentum with the launch of Sansad Adarsh Gram Yojana [SAGY] [2] [3] by Prime Minister Narendra Modi on October 2, 2014, Gandhi's birthday, in addition to Smart Cities and Digital India, as a development program for India. The Eco Needs Foundation has initiated the concept of "Smart Village" by adopting villages and providing basic amenities like sanitation, safe drinking water, internal roads, etc. In the "Smart Village" concept, the development of the village is based on five paths: retrofitting, redevelopment, green fields, e-pan, and livelihood.

Need for Smart Villages in India

The idea of a smart village in the present day seems possible, as the cities have started overflowing and their expansion is limited, which is leading to the creation of urban jungles, where the population density is increasing beyond the norms. As of 2011, there are about 649,481 villages in India, and more than 800 million people reside in villages, and about 50% of the village population is under 25 years of age. Which means the majority of people are still staying in rural areas, trying to migrate to urban areas for better career opportunities and lifestyle upliftment. Villagers have all the potential for development socially, economically, and environmentally, but they lack even basic amenities, which makes them incompatible. If we understand the ecosystem of the Indian villages, there are many avenues to make our villages and our country a sustainably developing nation. A smart village concept is that its people are very well

aware of the available resources, applicable services, various schemes and programs, etc., by which the villagers can benefit. Technology as a means of development, enhancing education, agriculture, and local art & tradition to create entrepreneurial opportunities, improving healthcare facilities, and overall enhancement of rural areas are initiatives upon which a smart village puts a major thrust. The Smart Village concept is needed for a sustainable and secure future for the villagers. Achieving higher goals without compromising the roots and identity of the rural through sustainable development and smart technology interventions.

1.3 Smart Village Initiatives in India and Gujarat

Smart Village Initiatives in India

Some Smart Village Initiatives in India:
1. Digital India Program
2. Sansad Adarsh Gram Yojana [SAGY]
3. Smart Village Initiative by IIT Madras
4. Mahatma Gandhi National Rural Employment Guarantee Act [MGNREGA]
5. Unnat Bharat Abhiyan
6. E – panchayat
7. Solar Charkha Mission
8. National Rurban Mission [NRuM]
9. Deen Dayal Upadhyay Gram Jyoti Yojana

Smart Village Initiatives in Gujarat

The Government of Gujarat launched the Smart Village program on 22 May 2014. The objective of the program was to make villages self-reliant and clean. It was conceptualised in line with the Smart City initiative of the Central Government, under which 100 cities were selected for infrastructure development.

Some Smart Village Initiatives in Gujarat:
1. E – Gram Vishwagram Project
2. Smart Village Pilot Project
3. Sujalam Sufalam Yojana
4. Mukhyamantri Gramodaya Yojana
5. Digital Literacy Campaigns
6. Healthcare Initiatives
7. Educational initiatives
8. Smart Governance
[2][3]

2 AIM & Objective

2.1 AIM

To investigate and propose strategies for utilising resources through smart infrastructure planning in Lakhtar, with the aim of promoting sustainable development, enhancing quality of life, and fostering economic growth in rural communities.

2.2 Objectives

1. To identify gaps in existing infrastructure through analysis and stakeholder consultations to pinpoint areas for improvement

2. To explore opportunities to develop smart infrastructure solutions that leverage available resources efficiently, enhance connectivity, improve service delivery, promote sustainable development, and integrate various infrastructure components.

3. To maximize resource utilisation, minimize costs, and enhance the overall effectiveness and resilience of rural development initiatives.

2.3 Scope of the study

The study area, Lakhtar located in Lakhtar taluka of Surendranagar District, Gujarat, is selected mainly for it functions as a large village and the administrative headquarters of the Lakhtar Taluka [sub-district]. It means many villages within Lakhtar Taluka are very much dependent on Lakhtar village for their major administrative work and basic amenities like Healthcare facilities, Schools, Markets, etc.

The Study emphasises on infrastructure of lakhtar that helps create sustainable rural growth – transportation, water supply, sanitation, energy, solid waste management, digital infrastructure, and skill development.

3 Research Methodology

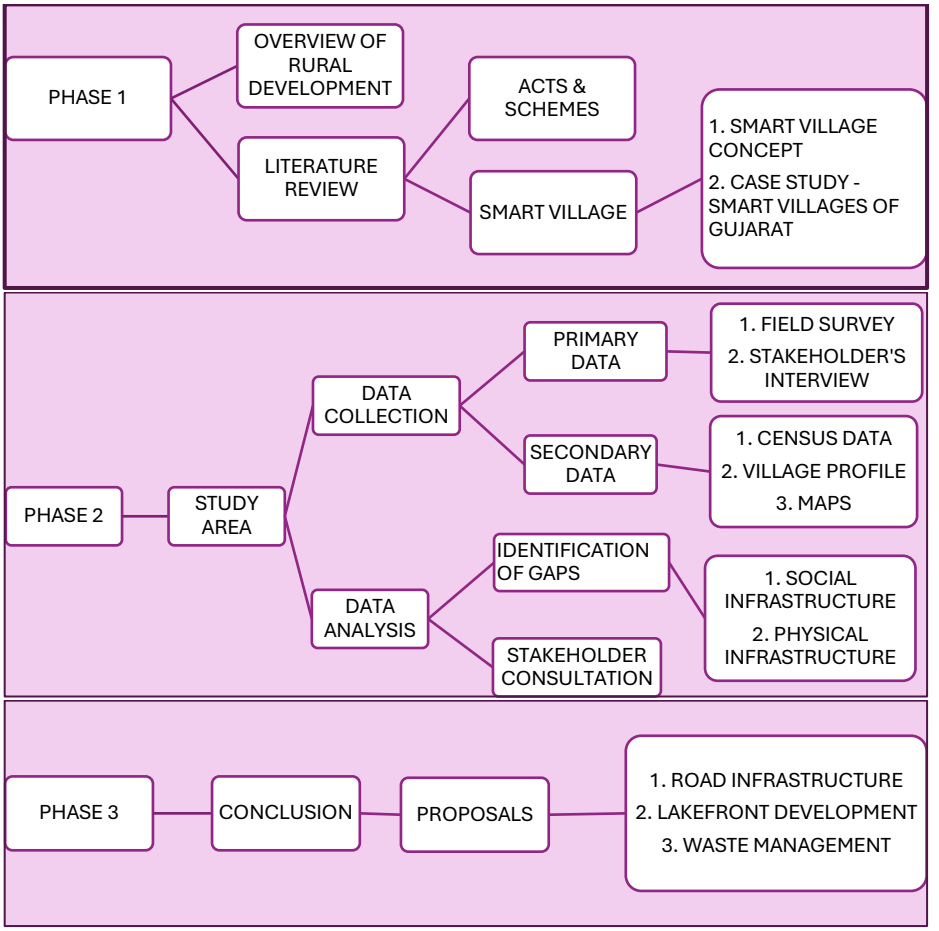

Fig. 1. Research Methodology

4 Assumptions and Limitations

This study is based on certain assumptions necessary to enable future-oriented infrastructure planning at village scale using available secondary data, field surveys, and planning norms (See figure 1).

1. Population Projection: Population for the year 2041 is projected using the incremental increase method based on Census data from 1991, 2001, and 2011, assuming a stable growth trend.

2. Planning Norms and Resource Demand: Water demand is calculated using URDPFI norms [40 LPCD]. Solid waste generation is assumed at 300 g per capita per day as per the Solid and Liquid Waste Management Report [4].

3. Waste Segregation Efficiency: Source segregation efficiency is assumed at 80% for the projected year 2041, based on benchmarks from model villages under Swachh Bharat Mission Phase 2. The proposed systems remain viable ± 10% variation in segregation efficiency.

4. Technology Performance Parameters: Performance of proposed smart infrastructure [solar street lighting, biogas plant, Ro plant, smart bins] is based on standard MNRE and CPCB guidelines and manufacturer specifications.

5. Institution and Community Support: The study assumes continued institutional support from the gram panchayat and basic community participation for operation and maintenance of the proposed infrastructure.

5 Limitations

1. Financial Analysis: Detailed capital and life-cycle cost assessments were beyond the scope of the study; investment levels are therefore indicated qualitatively.

2. Data Constraints: The analysis relies partly on secondary data sources, which may not fully capture recent on-ground changes.

3. Operational and Maintenance Risks: Long-term performance of proposed systems depends on effective local operation and maintenance, which may vary in practice.

While the framework is replicable for semi-arid rural settlements, outcomes may differ based on governance capacity and local socio-economic conditions.

6 Case Study

Table 1. Filtering criteria

Sr. No.	Village	Area	Population	Houses	Before Development	Village Development schemes & policies applied	Special Features
1	Dhanora, Rajasthan	412 Ha	821	181	Poor roads hindered connectivity. Open defecation was prevalent. Clean water, electricity, and proper housing were scarce	Soch Badlo Gaon Badlo [SBGB] Sanitation	Eco Needs Foundation
2	Dharmaj, Guajrat	1461.11 Ha	10,429	2232	Lack of basic amenities Roads were made of stone Poor drinking water & sanitation	Avichal Heritage Initiative	Global Village, most wealthiest & literate
3	Hiware Bazar, Maharashtra	976 Ha	1233	216	1972 drought leading to mass exodus Villagers migrated to nearby urban areas Water scarcity High Crime rates Villagers engaged in liquor business	Adarsh Gaon Yojana [AGY] or Ideal Village Scheme Employment Guarantee Scheme [EGS] Rainwater harvesting Drip irrigation Social reforms	Popatrao Baguji Pawar Known for it's Irrigation facilities Home of about 60 millionaires

4	Akodara, Gujarat	466 Ha	1191	236	Facing challenges like cash transactions, limited infrastructure, and traditional livelihoods	Digital Literacy Skill Development Animal Husbandry Financial Inclusion	First Digital Village
5	Kamrol, Gujarat	10.1 Sq. km	2097	441	Infrastructure gaps Migration pressure	Vishwakarma Yojana Scheme	Rurbanizatio n concept bridging rural and urban features
6	Kolavad a, Gujarat	1216 Ha	1908	389	Inadequate facilities, limited infrastructure	Holistic Village Development Program [HVDP] Smart Village Initiative Model Cooperative Village [MCV]	
7	Dharnai, Bihar	305 Ha	3207	450	Lack of access to electricity since 30 years Diesel generators were used causing unhealthy environment Over 4 million people died prematurely due air pollution	Solar-Powered Micro-Grid Energy Independence Advocacy and Inspiration	India's first fully solar-powered village
8	Punsari, Gujarat	1395.6 Ha	5100	1109	lacked basic amenities, including uninterrupted	"Pradhan Mantri Adarsh Gram	Punsari Model got replicated in

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	water and electricity supplies. There were no toilets, and infrastructure was minimal	Yojana [PMAGY] Deen Dayal Upadhyaya Grameen Kaushalya Yojana [DDU-GKY] Sansad Adarsh Gram Yojana [SAGY] Integrated Rural Development Programme [IRDP] Mukhya Mantri Adarsh Gram Yojana [MMAGY]"	over 300 villages

[5][6] The proposed smart infrastructure interventions for Lakhtar draw upon lessons from successful rural development models documented in the literature (Table 1). The punsari village model demonstrates the effectiveness if ICT-enabled governance, infrastructure integration, and service delivery in enhancing quality of life. Hiware Bazar highlights the role of community participation and decentralized water management in achieving long-term environmental sustainability and economic resilience. The Dharnai solar micro-grid initiative underscores the potential of renewable energy adoption while also emphasizing the critical importance of long-term operation and maintenance strategies proposed for Lakhtar.

7 Study Area Profile: Lakhtar, Surendranagar

7.1 Introducion to Study Area

Lakhtar Villages is located in Lakhtar Taluka of Surendranagar District, within Saurashtra region of Gujarat, India (Table 2).

Surendranagar District (See figure 2)

- **16th District** in terms of Population in the Gujarat State
- **22nd dense district** with density of 144 / sq.km.
- One of **the largest producers of quality Shankar cotton in world**.
- Total 574 villages
- **It has 2nd highest no. of educational institutes per capita**
- Many Newspapers are published from Surendranagar in Gujarat

Surendranagar District consists of 3 Prant [Revenue] dividing the region into talukas

Table 2. Three Prant of Lakhtar District

Division	Wadhwah	Dhangadhra	Limbdi
Taluka	Wadhwah	Patadi[Dasda], Halvad,Lakhtar, Dhangadhra	Chotila, Limbdi, Muli, Sayla

- District's Economy depends on agriculture with 62% of workers engaged in agricultural work
- Business: MSMEs & industries
- Major Trade & Processing centre: Agricultural products, cotton, bearings, ceramics sanitary ware and basic metal & allot industries.

Fig. 2. Location Map Surendranagar District [Source: Surendranagar District Website]

Lakhtar Taluka

As per Census 2011, there are 43 villages in Lakhtar Taluka of Surendranagar, Gujarat. Geographically Lakhtar is the largest village with 57.41 sq. km area having the highest population. Whereas Babajipara is the smallest with 4.62 sq. km area. [7]

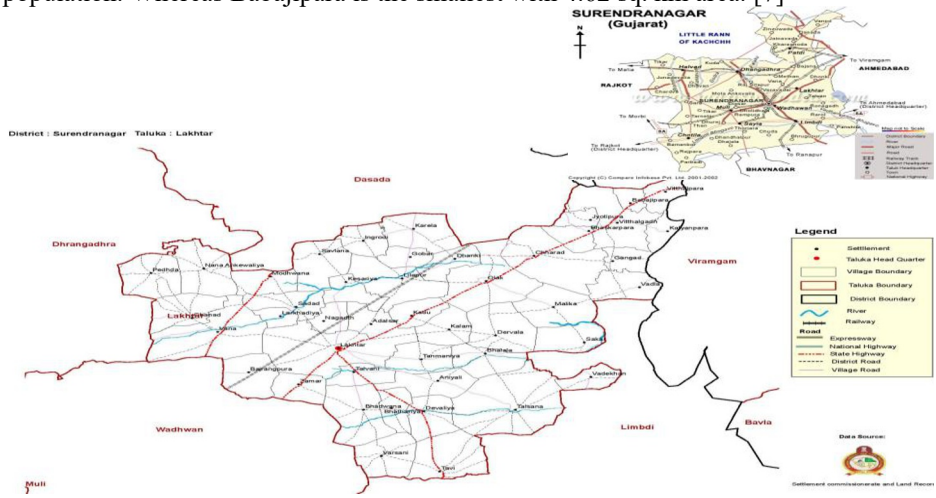


Fig. 3. Lakhtar Taluka Map [Source: Surendranagar District website]

Taluka is known for its cultural heritage, local traditions, and developing infrastructure (See figure 3). The area offers a blend of historical significance, natural beauty, like Nal Sarovar bird century, Vadla bird view point, and Hawa Mahal Dhanki, making it a key part of the region's identity.

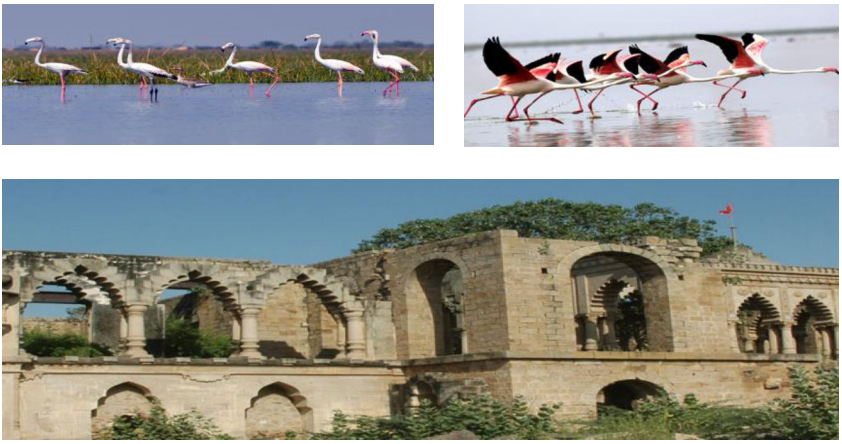


Fig.4. 1. Nalsarovar, 2. Vadla bird viewpoint, 3. Hawa Mahal Dhanki [Source: Online Images]

Lakhtar Village

The Village serves as the taluka headquarters, with balanced characteristics of rural settlement and administrative significance. Its geographical location and demography makes it a case for examining challenges and opportunities in rural infrastructure development and resource optimization. As per Census 2011, Lakhtar village has a population of 12,371[7], agriculture as the primary economic activity with basic infrastructure amenities. Cotton, Groundnuts, Millets, and pulses are major crops cultivated here whereas animal husbandry, particularly dairy farming is a secondary source of income. There are many cottage industries such as pottery, handicrafts, and cotton pressing, indicating a mixed economy.

Fig.5. Views of Lakhtar Village

Culturally, Hinduism is the predominant religion, with temples and chowks as key social nodes. Primary language spoken here is Gujarati, while Hindi and English are also used for education and administration.

Lakhtar was also known as a princely state, a major native state during British Rule in India (See figures 4-9). It was composed of around 50 villages. Historically, it was known as Jhalawad. The Jhala Rajputs founded it in 1604 and ruled it with the title of Thakur Sahib during the British Rule. After independence, the region became part of the Surendranagar district. The royal legacy can be seen in the Lakhtar Fort, which is a major cultural and architectural landmark of the region The fort is built in traditional Rajput architectural style. The stone walls, and gateways, serve as a protection wall to the residential quarters, courtyards and granaries within.

Fig.6. Lakhtar Fort Walls

Fig.7. Lakhtar Fort Gateway

Motisar lake and Kadesar lake, signifies the natural beauty of the village and are a very important for water management, ecology and community life here.

Fig.8. Motisar Lake

Lakhtar can be said to be a very good combination of social, cultural (Temples etc) and ecological system. Table 3 below gives a summary of the village settlement.

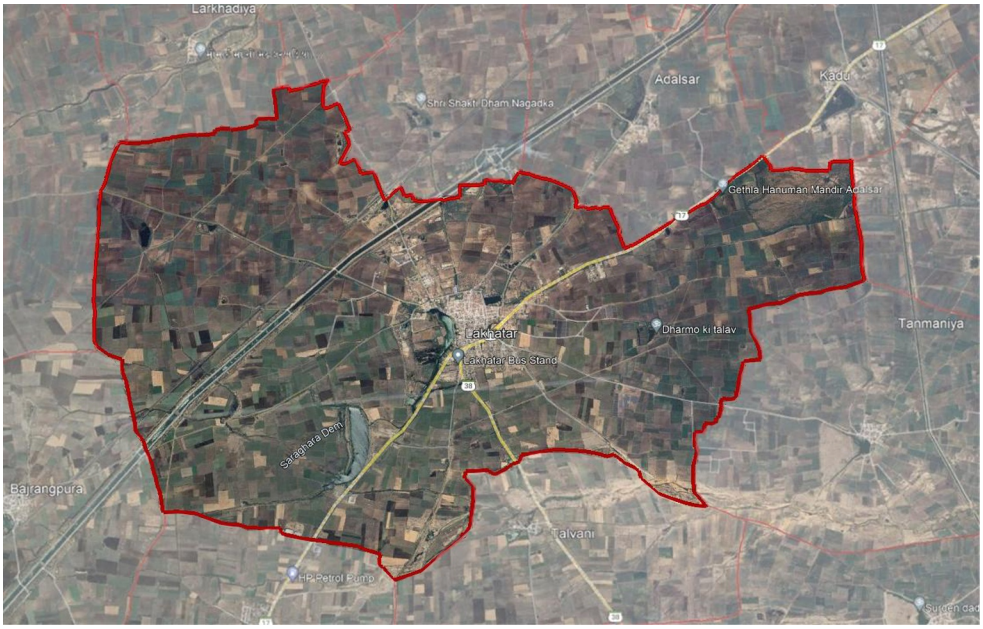


Fig.9. Village Boundary = 57.3 sq. km.

Table 3. Key Community and Heritage Nodes

Category	Examples	Significance
Temples	Ambaji Temple, Hanuman Temple, Khodiar Temple	Religious and community gathering centres
Chowks	Gandhi Chowk, Haveli Chowk, Khodiar Chowk	Social interaction and cultural events

Water Structures	Motisar Lake, Kadesar Lake, Matrima Vav	Water storage, ecological balance
Civic Institutions	Library, Guest House, Post Office, Taluka Shala	Educational and Public Services

8 Data Collection and Analysis

8.1 Population

Table 4. Population Distribution [7]

POPULATION DISTRIBUTION				
YEAR	**Gujarat [Rural]**	**Surendranagar [Rural]**	**Lakhtar [Taluka]**	**Lakhtar Gram Panchayat**
2001	31,740,767	11,127,00	69,551	12,050
2011	34,694,609	1,259,352	75,606	12,371

Table 5. Percentage Share of Population [7]

AREA	**Total Population [2001]**	**Population Share to upper spatial unit**	**Total Population [2011]**	**Population Share to upper spatial unit**
Surendranagar [Rural]	11,127,00	-	1,259,352	-
Lakhtar [Taluka]	69,551	8.67 %	75,606	6.0 %
Lakhtar [GP]	12,050	17.32 %	12,371	16.36 %

Table 6. Decadal Growth of Population [Census of India, 2011][7]

District	**1991**	**2001**	**2011**	**Decadal Growth % [1991-2001]**	**Decadal Growth % [2001-2011]**
Surendranagar	8,94,781	11,127,00	1,259,352	24.35	13.17
Lakhtar Taluka	46,626	69,551	75,606	49.16	8.70
Lakhtar Village	11,127	12,050	12,371	8.29	2.66

Table 7. Population Projection [7]

Population Projection [2041]							
Village	1991	2001	2011	2019	2021	2031	2041
Lakhatar	11,271	12,050	12,371	14,530	14,802	17,050	19,343

Population Projection is done using the Incremental Increase Method [Census of India, 2011] (See tables 4-7)

8.2 Literacy Rate

Table 8. Literacy rate [7]

Area	Surendranagar [Rural]	Lakhtar [Taluka]	Lakhtar [Village]
Literacy rate	73.19 %	69.8 %	66.58 %

8.3 Workforce Participation

As per Census 2011, Lakhtar Gram Panchayat has 4082 of total workers and almost 33% of the total population is the working population and so 63% of people are not active in any economic activities (See tables 8-10).

Table 9. Workforce Participation [7]

Area	**Main Workers**	**%**	**Marginal Workers**	**%**	**Non – Workers**	**%**
Lakhtar Taluka	29,850	33.28	4687	6.20	45,756	60.52
Lakhatar Village	4082	32.99	463	3.74	7826	63.26

Table 10. Distribution of workers [7]

Area	**Cultivators**	**%**	**Agricultural Labours**	**%**	**Household Industry Workers**	**%**	**Other Workers**	**%**
Lakhtar Taluka	8690	29.11	15,683	52.54	274	0.92	5203	17.43
Lakhatar Village	571	13.98	1457	35.69	57	1.39	1997	48.92

8.4 Social Infrastructure

Social Infrastructure in Lakhtar village comprises of education, Healthcare, financial and communication facilities that support basic lifestyle of the villagers

Education

Gram Panchayat has four level of educational facilities from kinder garden to college. There are 14 anganwadis, 9 primary schools. 6 secondary schools, and 6 senior secondary schools (See table 11). Most schools are equipped with mid-day meals, drinking water, toilets, electricity, and compound walls (See figures 10-11). The number of schools exceeds norms for primary and secondary levels, but the village lacks a college facility and a few schools require minor upgradation. [8]

Table 11. Education Facilities [9]

Type of School	Existing no. of Facility	Required	Gap
Anganwadi	14	3	
Primary Schools	9	4	5 [Surplus]
Secondary Schools	6	2	4 [Surplus]
Senior Secondary Schools	6	1	5 [Surplus]
Colleges	0	0	0

Fig.10. Brilliant School, Lakhtar

Fig.11. Jagatram Dave School

Healthcare Facilities

Healthcare facilities include 4 sub-health centers, 1 community health center and 1 maternity and child welfare center, as per the required norms (See table 12). Private hospitals, clinics, and medical stores supplement public services (See figures 12-13).

Table 12. Education Facilities [9]

Facility Type	Existing	Required	Gap/ Surplus
Sub-Center	4	4	0
PHC	0	0	0
CHC	1	0	+1
Maternity & Child Welfare Center	1	0	+1

Fig.12. Healthcare Center

Fig.13. Satyam Hospital & Laboratory

Table 13. Condition of Houses [Village Profile]

Housing Condition			
Total Houses	Good	Liveable	Dilapidated
2555	1661	858	12,371

Table 14. Ownership Status [Village Profile 2019][9]

Ownership Status [%]		
Owned	Rented	Any Other
86.8	10.1	3

As per Census 2011 there Total 2555 houses in village with average household size 4.84 and 98.4 % houses are residential (Refer tables 13-14).

Estimated population in 2041 is 19,343.

Calculating HH required in 2041 as per 4.84 HH size, 996 houses will are required
As per VDI 2021, the village has 4200 houses available currently which means, 204 houses are surplus for 2041.

Socio-Cultural Facilities

The village has a public park, community hall, and open-air theatre. The Park is currently non-operational and other facilities require maintenance.

Financial & Communication Facilities

Lakhtar has 3 banks, ATMs, co-operative societies post office, mobile connectivity, public library and other essential services.

8.5 Physical Infrastructure

Lakhtar village being the taluka headquarter has good level of infrastructure facilities – connectivity, water supply, sanitation, electricity, and waste management.
The study analysis the current condition of available infrastructure and identifies the gaps (See tables 13-14).

Roads & Connectivity

Lakhtar is located at junction of 2 state highways SH 17 and SH 38, and it is connected via district road to surrounding villages and towns. There are public and private buses operational regularly. Internal village roads are mostly pucca, but some areas needs repairs or paver blocks (Figures 14-15).

Fig.14. Existing condition of Raods

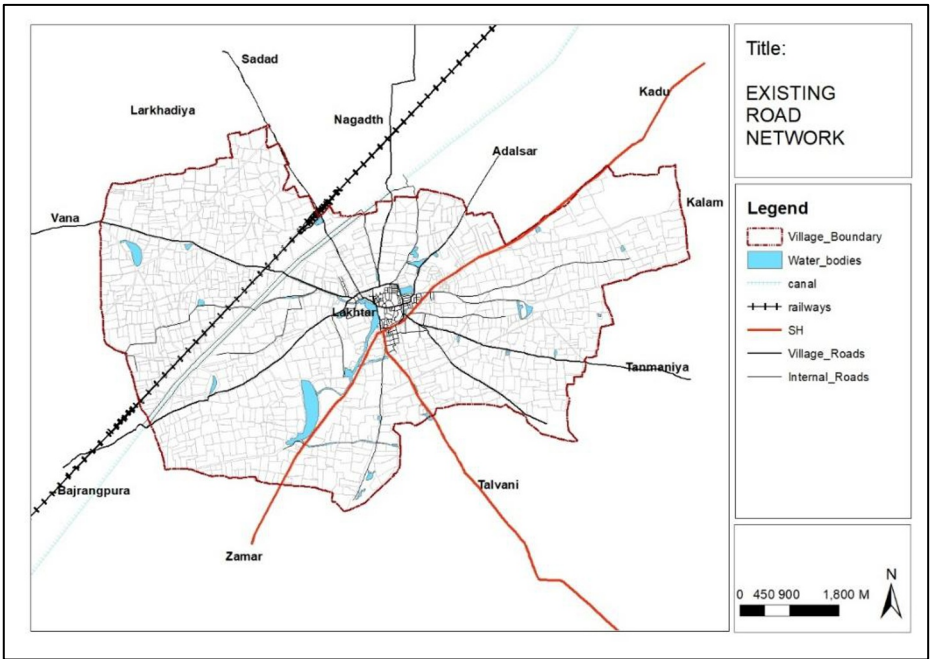


Fig.15. Existing Road Network, Source: Author's GIS analysis based on secondary data [Author, 2024]

Solid Waste Management

The Panchayat manages waste collection through door-to-door service once a week. Waste is dumped in a designated open site without treatment (Figures 16-17)
Current Scenario of Solid Waste Management:

Table 15. Current Scenario of Solid Waste Management in Lakhtar [10]

Parameter	Quantity/Status	Remarks
Waste generated per capita per day	300g	-
Total solid waste generated	280kg per day	-
Wet waste generated	-	50 % of waste generated is consumed by cattle
Dry Waste generated	350kg	-
Garbage nuisance points	6	-
Secondary bins	36	-

Solid Waste processing facility	None	Open Dumping
Approximate amount of waste on dumping site	5MT	-
Existing Dumping site area	6.12 Ha [Primary Source]	-

Fig.16. Images of Existing waste dumpsite

Fig.17. Location of existing dumpsite

Water Supply

The piped water network covers all households. There are 2 overhead tanks in the village but only 1 tank is operational [Capacity 1 million liters] and there are 2 underground sumps [7 lac litre capacity] properly working. Even though the Narmada canal water supply project by Government is trying their best to get Narmada River water to these villages there are still challenges for Lakhtar. (See figures 18-19)
Source 1 Solid & Liquid waste Report 2019

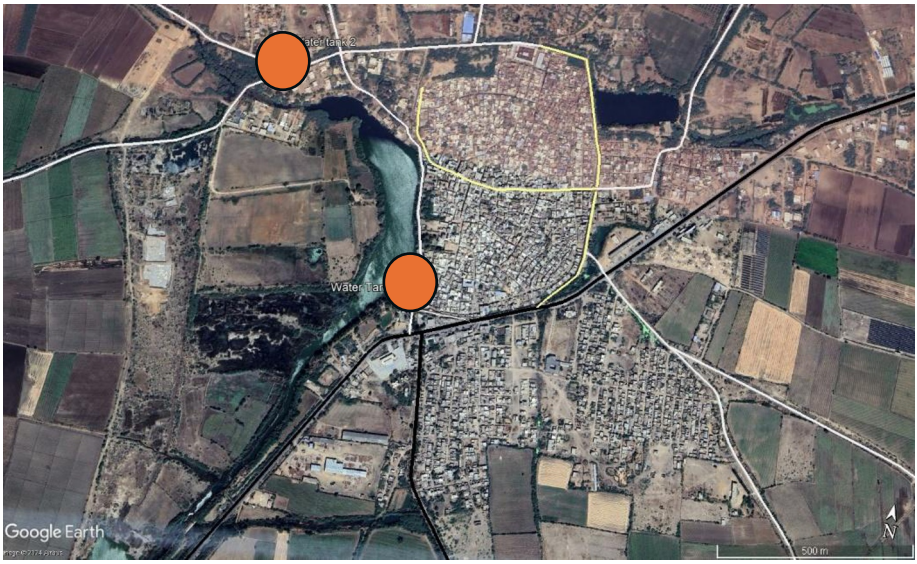


Fig.18. Location of Overhead water Tank

Fig.19. Image of existing overhead water tank

The current water supply is 27 LPCD, which is below the URDPFI standard. According to URDPFI guidelines, the maximum water supply norm for rural areas is 40 LPCD. [11]. So, for 12,371 [2011] persons, 496.84 kilolitres/day water supply is required, which is the current requirement
Whereas by 2041,
For 19,343 projected population required water supply will be 773.72 kiloliters/day. As per URDPFI guidelines, the maximum water supply norm for rural areas is 40 LPCD [11].

Sanitation

Current scenario states there is an open drainage network, carrying untrerated wastewater to natural water bodies in village.(See figures 20-21; Table 16)

Fig.20. current scenario of drainage in village

Fig.21. Existing Open drainage in village

Table 16. Existing Sanitation Facility [Village Report 2019][9]

Parameter	Count//Status
HH with toilets	3200
HH without toilets	154
Underground Gutter	2850
Open gutter / no connection	182
Public toilets	2
Door-to-Door waste collection	Once a week
Street cleaning	Once a week

Electricity

Electricity is supplied by PGVCL [Paschim Gujarat Vij Company Limited], with 24-hour availability. In case of faults in the power line, as the PGVCL sub-station (See figure 22) of 66 Kv is located in the village, they experience very less power cut issue which lasts for few minutes to max 2-3 hours (See table 17).

Table 17. Existing Power Supply & Connections

Responsible agency	PGVCL
Electric Sub Station	66Kv
Electric supply	24 hr
No. of Residential connections	3040

No. of Industrial connections	18
No. of Commercial connections	717
No. of Agricultural connections	14
3-phase electric supply	Yes
Solar street lights	No

Fig.22. Location of Electric Sub-Station, Lakhtar

8.6 Identified Issues

Based on the field survey, Secondary data analysis and stakeholder consultation of Lakhtar Village, many critical issues have been identified in infrastructure, environmental sustainability and climate resilience. The analysis highlights gaps in

physical and social systems, indicating areas requiring intervention to ensure sustainable rural development.

Transportation

Narrow and Congested Roads: Like many rural areas, Lakhtar also suffers from infrastructural limitations, particularly in road width and design. The primary approach roads leading into the village are narrow, which creates significant challenges like traffic congestion, safety concerns and limited capacity.

Insufficient connectivity: Lack of efficient transport links to neighbouring villages and major hubs.

Dependence on Private Vehicles: The village lacks a robust public transportation system, which makes it difficult for residents in and around lakhtar to commute to nearby towns or cities for work, education, healthcare or trade. This forces the villagers to use private transport options which again is difficult for them to manage its maintenance and repair. This also affects the socio-economic development as residents are cut off from broader opportunities.

Limited Road network: Existing road network does not effectively link Lakhtar with its neighbouring village or major roads such as state highway or rail network. This make it difficult for villagers to access external markets and resources which may hinder economic growth.

Water supply & Sanitation

Lack of clean drinking water: Adequate Clean drinking water is a necessity for any human being, but it's a challenge in Lakhtar.

Improper Sanitation: Poor drainage network and open system makes the living environment contaminated resulting into heath hazards.

Inadequate Water infrastructure: The existing infrastructure is insufficient for the village to meet the growing demands of the population. Pipeline are aging and dispite of several repairs issues does not resolve completely. Inadequate storage facility and lack of proper water treatment plant contributes to create challenge in proper water supply.

Water quality: Due to lack of proper filtration and treatment facilities, the current water may contain contaminants such as high levels of minerals, bacteria, and pollutants, questioning the standards of clean water safety. Improper disposal of wastewater that merges with natural water bodies in village like Motisar Lake & river waterways. This not only leads to contamination of the water sources but also affects the ecosystem.

Such contamination degrades water quality and poses serious health risks to the community.

Solid Waste Management

Current Waste management practices lacks an organized and systematic approach to waste collection, segregation, and disposal. As a result, waste is often disposed of haphazardly, leading to the accumulation of garbage in public spaces, streets, and around water bodies. Such practice not only creates unsightly conditions but also poses serious environmental and health risks.

Energy

Lack of renewable energy sources: It is observed that the villagers have heavy reliance on conventional energy sources with minimal adoption of renewable energy solutions. Despite the increasing global focus on sustainability, lakhtar has not yet harnessed the potential of renewable energy sources such as solar lights or biogas plant.

Environmental Challenges

Depleting natural Resources: Motisar lake

Motisar Lake has historically been a crucial water source for the villagers of Lakhtar, sustaining the community for generations. The lake's ability to store rainwater was once more than sufficient to meet the year-round needs of the villagers. This natural resource was integral not only to the daily lives of the residents but also to the agricultural practices that supported the local economy.

Currently the reliance on the Narmada Canal Project to fill the lake has marked a significant shift in how the lake is utilized. This supply of water highlights the diminishing self-sufficiency of the lake as a natural water body.

The practice of using Motisar lake for washing clothes and other activities has led to the contamination of its waters. The introduction of soaps, detergents, and other pollutants into the water poses a serious threat to both human health and the ecosystem of the lake.

The physical state of Motisar lake is also deteriorating due to inadequate maintenance. The peripheral walls of the lake are breaking down, that not only reduces the water holding capacity nut also exposes it to further contamination as waste and debris from the surrounding areas can easily enter the water. The neglect in maintaining the lake's infrastructure reflects a broader issue of resource management and highlights the urgent need for intervention to restore and conserve this vital water body.

Governance Challenges

Lack of Participation: Very limited involvement of local communities in the planning and decision-making process.

9 Proposals

9.1 Enhancing Connectivity

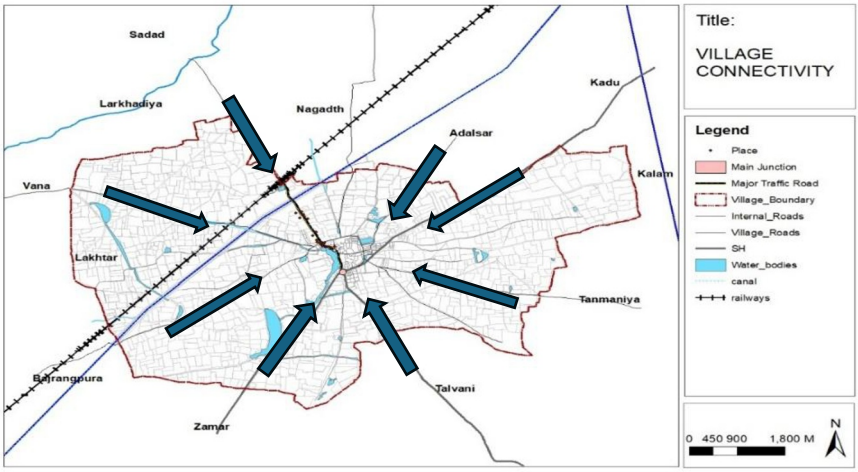


Fig.23. Map showing village connectivity & Major roads, Source: Author's GIS analysis based on secondary data

10 All inter-village roads are gathering towards the approach road of Gram Panchayat. (See figures 23-25)

- All neighboring 11 villages have to pass by Approach Road, Lakhtar GP to go to Lakhtar Railway Station or any other village
- This makes it a heavy traffic road.

Fig.24. Main Approach Road

- There are also many important activities on that are located exactly on this road , to make it ease to understand A1 and A2 are 2 PATCHES marked in the figure 24 below.

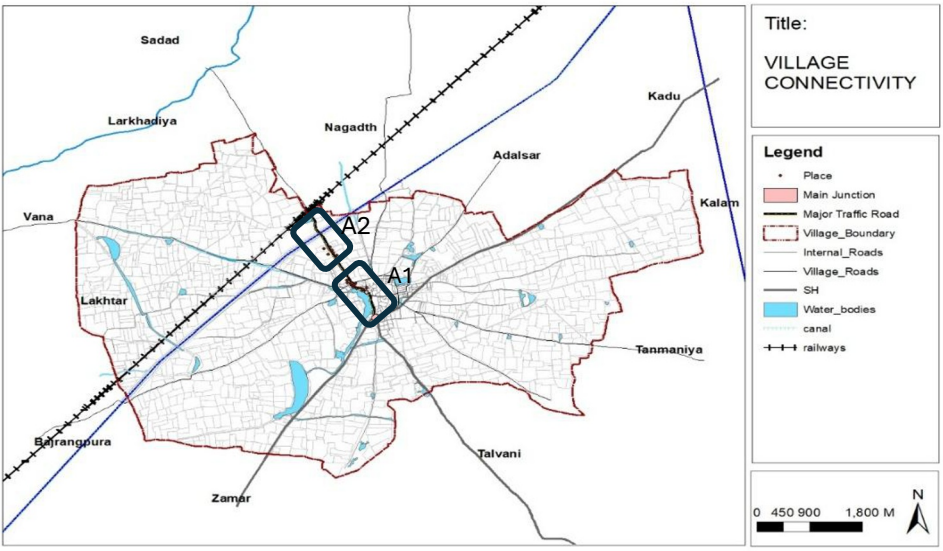


Fig.25. Map highlighting the 2 main Patches of Main Approach Road, Source: Author's GIS analysis based on secondary data

Important activities on the road

PATCH A1 (See figure 26)

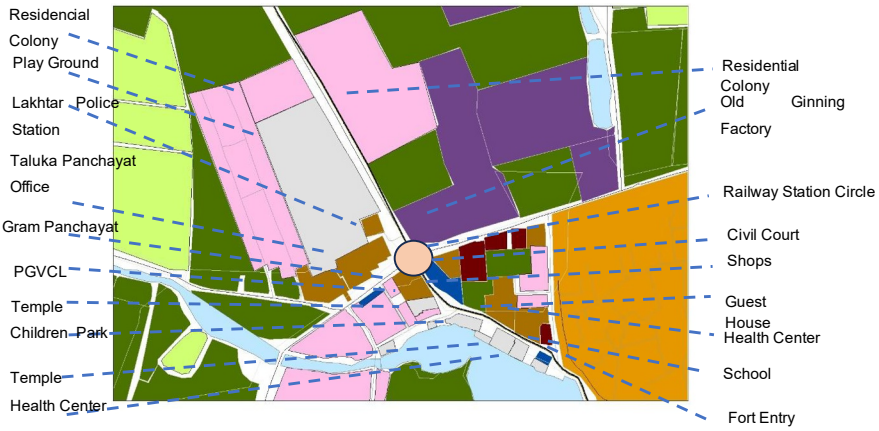


Fig.26. Some Important places & activities on Approach Road

PATCH A2 (See figure 27)

Fig.27. Some Important places & activities on Approach Road

Proposed Alternate Routes:

- **B1 is a 9 m wide proposed road, 2657 m long:** Connecting SG 117, Adalsar village & Nagadth Village to Lakhtar approach road near APMC

- **B2 is a 9 m wide proposed road, 3957 m long:** Connecting SH 17, Bajrangpura village & Vana village to Lakhtar approach road near APMC
- **B3 is 6 m existing Kutcha Road 1169 m long:** connecting internal village road & SH 17 through solid waste dumping site
- Proposal is to make a pucca road and widen it to 9 m (See figure 28)

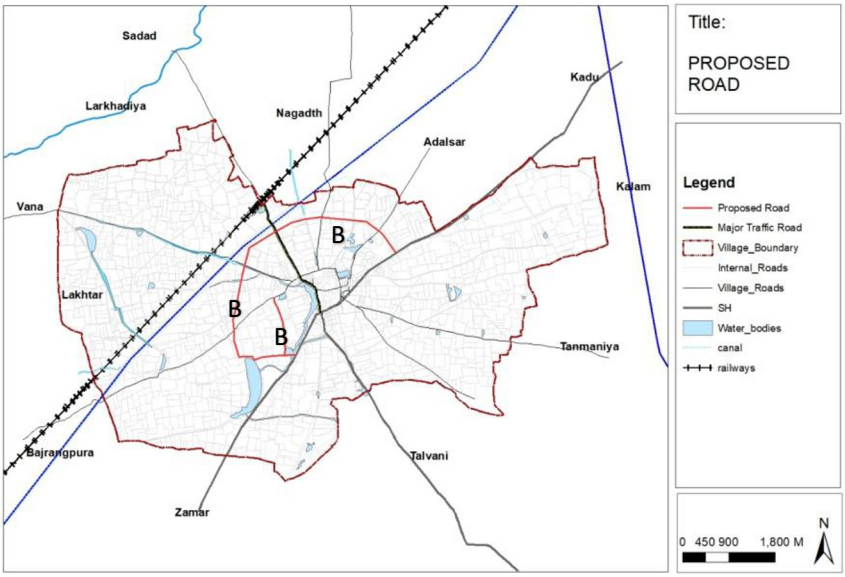


Fig.28. Map Of Proposed Roads, Source: Author's GIS analysis based on secondary data

Smart Intervention Proposals

Proposed Smart Street Lights:

- **Approximately 200 Smart Street lights at a distance of 40 meters are proposed along the proposed roads B1, B2 & B3**
- **Solar-Powered LED Street Light with Auto Intensity Control:** This system harnesses solar energy during the day to power LED lights at night and adjusts the intensity of the light based on ambient conditions and traffic movement.

Fig.29. Image Showing Solar Powered LED Street Light [Source: Online Image]

Sustainable Smart Bus Stops

Proposal of 6 New Sustainable Smart Bus Stops at specific locations marked in fugure 29 below, which will provide the villagers an ease to commute in and around the region. (See figure 29)

Features:

- Solar Powered bus stop with Pay & use Toilet facility
- Security Camera
- LED Screen for real-time information of bus
- Drinking water facility
- Mobile charging ports

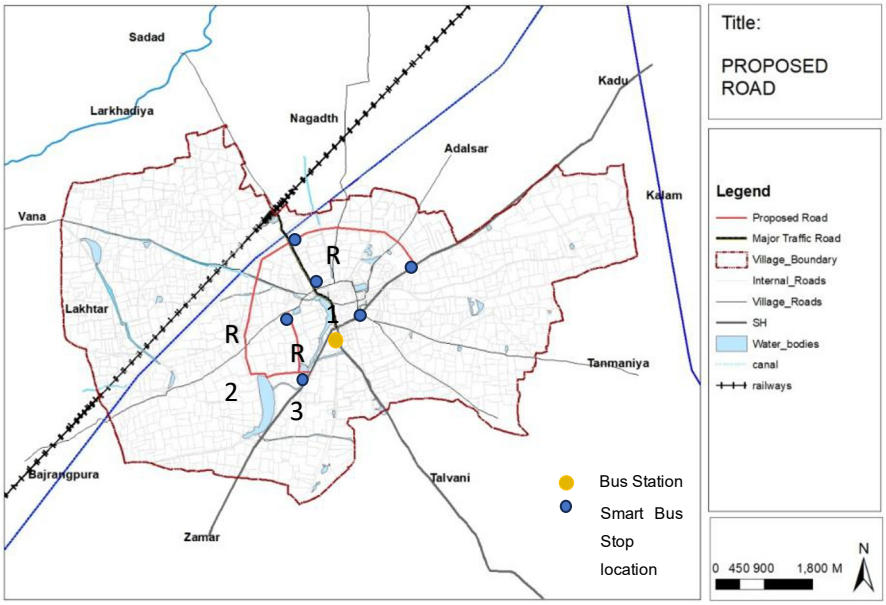


Fig.30. Map of Proposed Sustainable Smart Bus Stops in Village, Source: Author's GIS analysis based on secondary data

Bus stop locations cover almost all-important places like schools, hospitals, Government offices, Shops and Restaurants. (See figures 30-31)

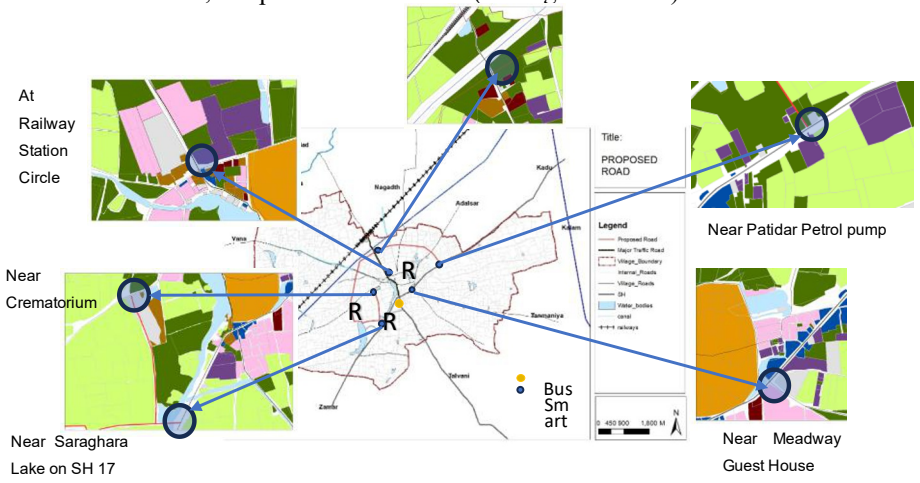


Fig.31. Proposed Sustainable Smart Bus Stops Locations,Source: Author's GIS analysis based on secondary data

a. Proposal 2 - Motisar Lakefront Development

Area = 14 Ha

Located at the entrance of the village approach road giving a very pleasant natural scene. It is a Perennial Lake, filled with water around the year. It serves as the basic source of water for Lakhtar village. (See figures 32-33)

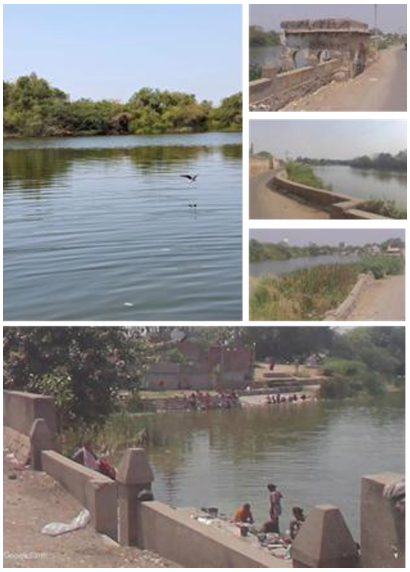
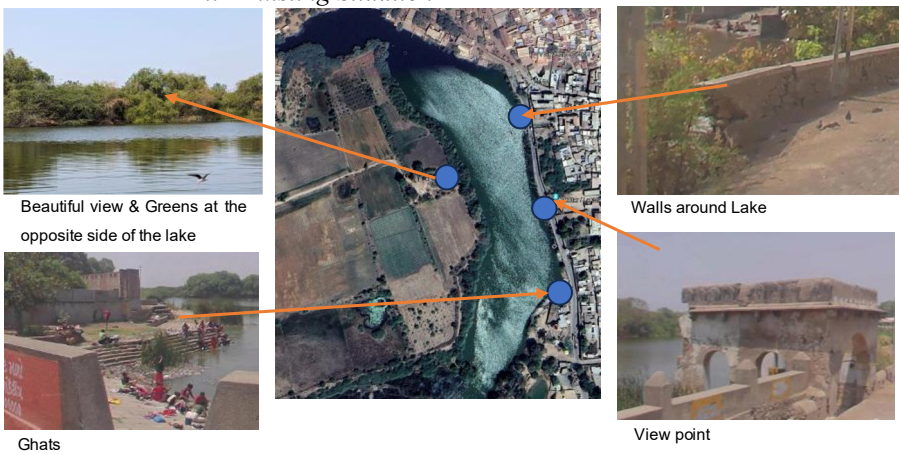


Fig.32. Images Showing Existing Scenario of Mitosar Lake

Fig.33. Location of Motisar Lake

i. Existing Situation



Issues Identified

- Lake wall & viewing point needs repairs
- Washing Clothes & Utensils at ghat makes the lake water impure
- Garbage in and around the lake creates unhealthy environment
- Lack of Cleaning and regular maintenance

ii. Proposed Recreational area along the lake for the villagers and visitors with:

- Children's play area
- Garden area
- Walkway
- Kiosks
- Public toilet
- Smart Drinking water facility
- Smart Surveillance

iii. Green Buffer

About 20 m – 50 m, wide along Green buffer is proposed on the westside of the lake.

As the natural water that gets collected in the lake comes from the west side of the lake, the Green Buffer is proposed there, which will act as a natural filter for the rainwater and help keep pollutants away from entering the lake, it will also be helpful to control the erosion and encroachment activities around the west side of the lake

iv. Proposed Smart Intervention:

- Smart Smart Pay & Use Toilet
- Kiosks
- Smart LED Screens
- Smart LED Street lights
- Smart Bins

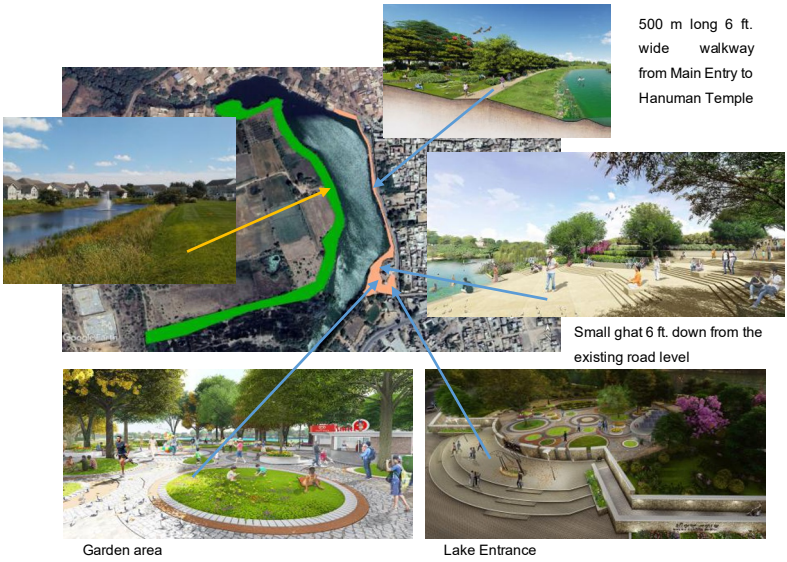


Fig.34. Some Reference images demonstrating the visual representation of the Lake development

v. Benefits

Motisar Lakefront development is a very important and big scale project. This will open many aspects like clean and green environment, generate economy, and enhance socio-cultural traditions amongst the community. (See figures 33-34)

The repaired peripheral retaining walls along with the view points, will protect the lake boundaries, the garden and jogging path along the periphery of the lake will restrict the contamination of the lake water by restricting the throwing of the waste, the recreational area will increase the visitors from around the village and create a good community gathering.

Smart interventions like smart public pay & use toilets, kiosks, Smart drinking water facilities, etc, will help operate the region smoothly and also help to create awareness among the villagers.

b. Lakhtar Fort Conservation

Lakhtar fort has a significant historical value, built around 140 years ago, by Thakor sahib Karansighji. It is also considered as the only fort in very good condition in Gujarat. It also proved to be a saviour to the villagers during flood of 1970.

i. Existing situation of Fort

Broken Chajja & Cracks on wall

Cracks on wall & Gap between bricks

News Article on fort condition (Source: Online

Bushes growing from between the walls

Broken Structure

Fig.35. Images highlighting the deteriorating condition of for

Observations made by field visit, and considering certain news articles it clearly state that the fort needs repairs. There are structural damages, erosion and weathering effects, and biological growth very clearly seen at the certain parts of the fort walls (See figure 35).

Despite of many efforts and some immediate repair works the fort's condition is getting deteriorated.

ii. Proposal for Lakhtar Fort Conservation:

1. Introducing Smart Surveillance at all the gates of the fort that will enhance the security and control the activities in and around the fort walls
2. Self-Healing mortar that repair small cracks autonomously, extending the longevity of repairs.
3. Documenting the whole fort area with precise GIS mapping and create 3D laser scanning model that will help provide detailed analysis and monitor fort's structural information.

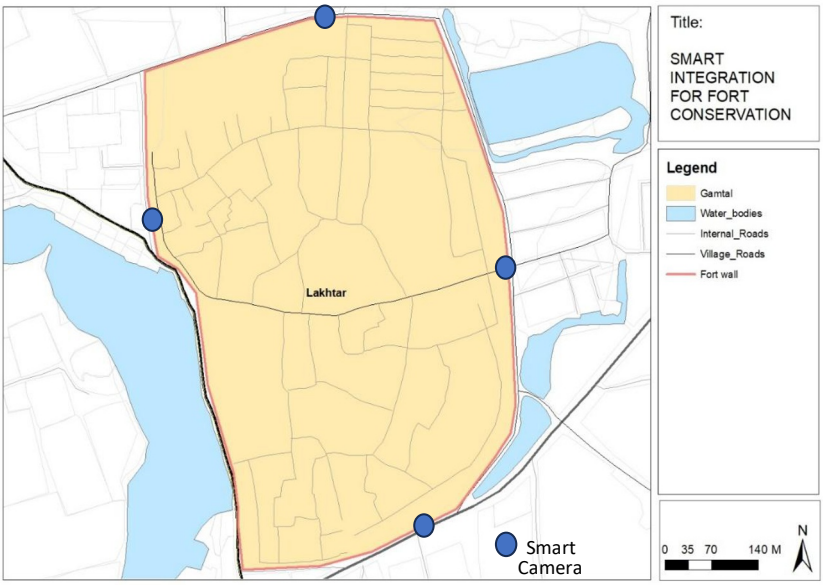


Fig.36. Map highlighting the Lakhtar Fort Walls and entry gates, Source: Author's GIS analysis based on secondary data

c. Solid Waste Management

As per the current scenario there are many efforts made by gram panchayat for waste management, but they are not enough like door-to-door waste collection, street sweeping, putting waste bins at certain areas etc (See figures 36-37).

As the waste collected is directly dumped at the dumpsite about 1.2 km away from gram panchayat close to main approach road of the village. The dum waste is not segregated nor is given any treatment. This creates very harmful environment and may lead to serious disease affecting quality of life.

Fig.37. images showing the existing dumpsite

i. Calculating the Solid waste generation for year 2041:

Waste generation is assumed at 300 grams [0.3kg] per capita per day. [10]

Total waste generation per capita
= 0.3 kg * Population [2019]

As per population projection [Table no. 6] above population in 2019 is 14,530,
= 0.3 * 14530 [as per Table no. 6] = 4,359 kg per day

For 2041,
Total waste generation will be 0.3 kg * 19,343 = 5802.9 kg per day

Hence estimated annual waste generation in year 2041 will be 2,118 tons

Assuming that 80 % [4642.32] of waste is getting segregated properly at the source, the composition of waste generated annually will be as per table given below:

Table 18. Waste Segregation % share for [2041]

Waste Type	Amount [kg/day]	% of total waste
Organic waste	2321.16	50%
Recyclable waste	928.46	20%
Non-Recyclable Waste	928.46	20%
Inert Material	464.23	10%
Total	4642.32	100%

Based on the assumption above the amount of Waste disposal at dumping site will be 1450.72 kg per day [if 25 % of the total waste goes to dumpsite] (See table 18)

Proposal for Solid waste management:

1. Relocating the dumping site:

Existing Dumpsite: 6.12 Ha area

Fig.38. Location of Existing dumpsite

Currently the dumping site is 1 km away from gram panchayat and less than 1 km from residential area. It is hardly 800 m away from Motisar Lake. (See figure 38)

Considering the criteria for identifying dumping site as per Solid Waste Management rules, 2016 the proposed site is identified:

Criteria for dump site selection:
The site selection follows the criteria specified under Solid Waste Management Rules. [4]

- Site Location must be atleast 100 meters away from rivers, & streams, 200 meters away from ponds, lakes and other surface water bodies, 200 meters away from highways and 200 meters away from habitations, public parks and water supply wells. It should be accessible by road, must be a stable ground and a buffer zone must be maintained around the site with an installed capacity exceeding five tonnes per day. (See table 19)

Proposed dumpsite:

Table 19. Proposed dump site details

Parameter	Value
Design life	10 years
Required area	1.6 Ha
Proposed total site	10 Ha [inc. buffer, composting leachate pond and access]
Distance from settlement	>500 m
Waste Density	500 hg/m3

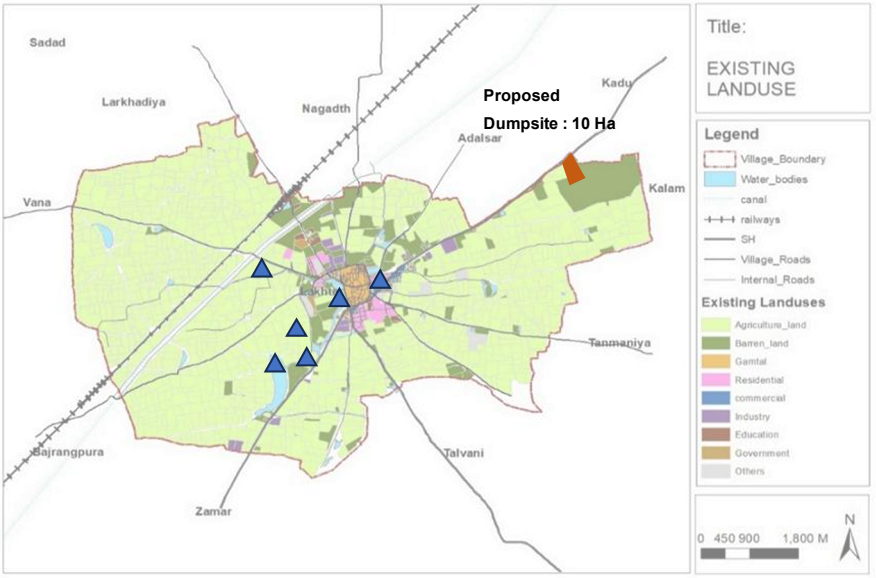


Fig.39. Proposed dumpsite and smart bins location, Source: Author's GIS analysis based on secondary data

Features of proposed dumpsite:

- Waste Segregation and Material Recovery Facility
- Composting unit for organics
- Leachate management and green buffer around site

Proposed Sustainable and Smart Intervention:
Solar- powered trash compactor bins:

- Proposing 6 large bins at major areas with trash compactor and replacing the existing 36 bins with GPS-tracker and additional 50 bins with GPS tracker.
- Route optimisation for collection vehicles using mobile tracking (See figure 39)

Biogas Plant:

Proposal of the installation of a biogas plant for sustainable energy generation and waste management

Biogas plant details:

For 2041, Population as per table 6 will be 19,343

The proposed plant is fixed dome biogas plant with organic waste as input material and Output products can be cooking, lighting and electricity generation, Bio-slurry as fertiliser

Daily waste quantity: 1092.75 kg per day

Biogas Yield : 0.03 m^3 per day

Daily Biogas Production" 32.78 m^3 per day

Retention Time : 30 days

Digester Volume : 983.4 m^3

This installation will benefit the environmental impact, the economy and social impact.

d. Reverse Osmosis [RO] Plant

Need for RO plant:

As shown in the figure below the salinity in the land is very high due to which the whole green marked area cannot use ground water.

The existing water sources are contaminated with pollutants, making it unsafe for villages for consumption.

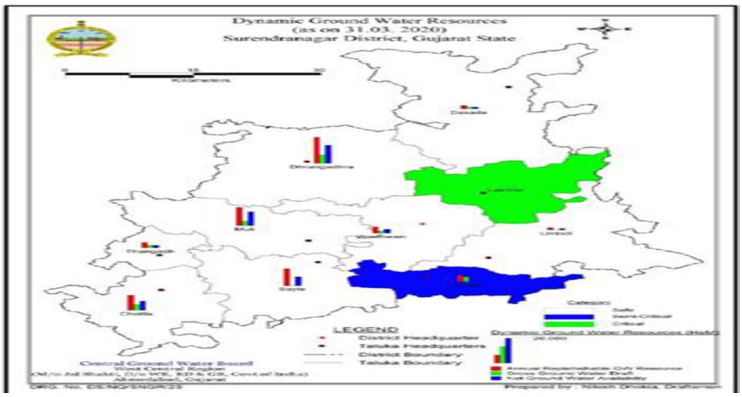


Fig.40. Map showing Dynamic Ground Water Resource, Source: Aquifer Mapping and Management of Ground water Resources, Surendranagar District. [12]

Taluka Wise Ground Water Resources, Availability, Utilization and Stage of Ground Water Development (2020)

Taluka	ANNUAL REPLENISHABLE GROUND WATER RESOURCE (mcm)					Natural Discharge during non-monsoon season (mcm)	Net Annual Ground Water Availability (mcm)	ANNUAL GROUND WATER DRAFT (mcm)			Projected Demand for Domestic and Industrial uses upto 2025 (mcm)	Ground Water Availability for future irrigation (mcm)	Stage of Ground Water Development (%) (12/9) * 100	Category
	Monsoon		Non-Monsoon		Total Annual Ground Water Recharge			Irrigation	Domestic And Industrial uses	Total				
	Recharge from rainfall	Recharge from other sources	Recharge from rainfall	Recharge from other sources										
LAKHTAR	0	0	0.00	0.006	0.006	0.0006	0.0054	0	0.00	0	0	0.0054	0.00	salinity

Fig.41. Water Resource availibility , Lakhtar, Source: Aquifer Mapping and Management of Ground water Resources, Surendranagar District. [12]

As per the field survey it was identified that there is no filteration / treatment plant available in the village for treatment of the water, which raises the need for a RO plant here.

Proposal:

An advanced RO technology Plant is proposed with 800 m^3 capacity. Providing community water points at public areas and training staff on plant operation and maintenance. (See figure 40-44)

As per URDPFI guidelines, the minimum water supply norm for rural area is 40 LPCD. [11], and as per table no. 6 projected population in 2041 is 19,343, so total water requirement will be 773.72 m^3 per day.

Fig.42. Image showing location of proposed RO plant in Village, Source: Author's GIS analysis based on secondary data

The installed RO plant will improve the quality of water, enhance public health and community well-being. (See table 20)

e. Existing and Proposed Landuse Map

Existing Landuse as of Year 2024

Others	0.366	0.19

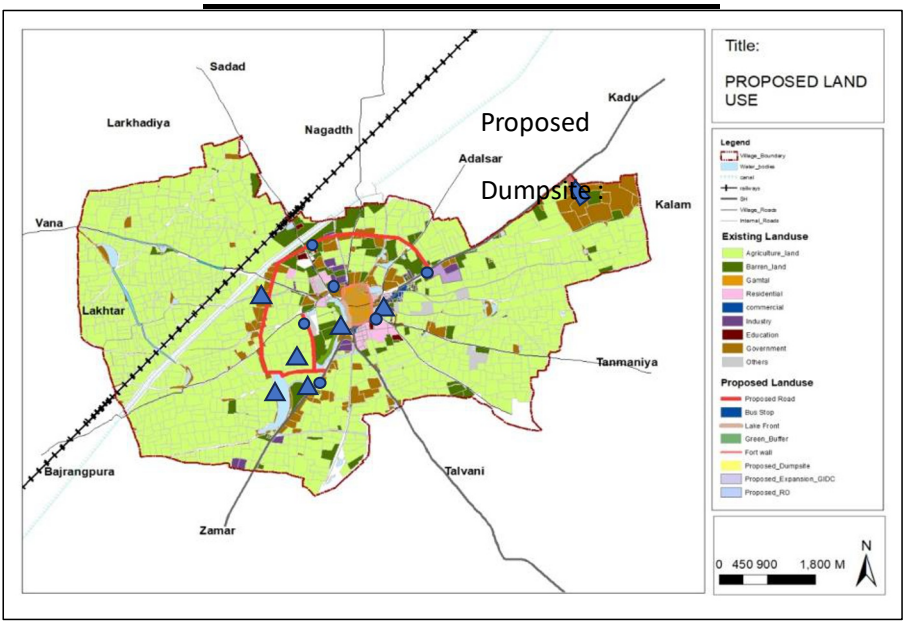
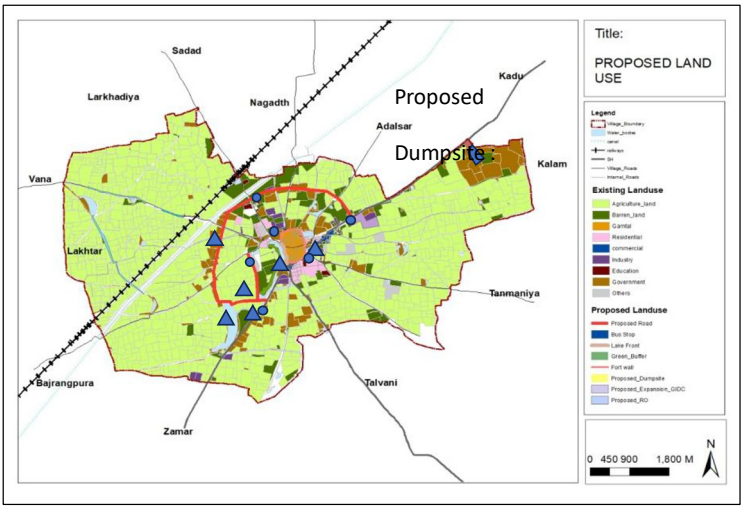


Fig.44. Map of Proposed Landuse along with the smart interventions of Lakhtar Village, Source: Author's GIS analysis based on secondary data

Table 21. Proposed Landuse area distribution table

Landuse	**Area** [sq.km]	%
Agriculture Land	32.54	80
Lake	0.829	1.86
Gamtal	0.340	0.89
Existing settlement	0.439	1.07
Industrial	0.536	0.18
Commercial	0.083	0.02
Education	0.100	0.26
Government buildings	0.160	0.39
Barren Land	4.125	4
Others	0.366	0.19



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Education	0.100	0.26
Government buildings	0.160	0.39
Barren Land	4.125	4
Others	0.366	0.19

10.1 Prioritisation of Proposals

To enhance implementation feasibility and decision making clerity, the proposed smart infrastructure interventions have been qualitatively prioritized based on relative investment requirements, expected social impact, and alignment with existing government policies and schemes. (See tables 21 and 22)

Table 22. Prioritisation of Proposed Smart Infrastructure Interventions

Proposal	Investment Level	Social Impact	Policy Alignment
Solid Waste Management with Biogas Plant	Medium	High	Swachh Bharat Mission [SBM], Solid Waste Management Rules
RO Water Treatment Plant	Medium	Very High	Jal Jeevan Mission, National Water Quality Sub-Mission
Motisar Lakefront Development	High	High	AMRUT, Tourism & Heritage Development Programs
Smart Bus Stops & Connectivity Improvements	Low	Medium	Rural Mobility Programs, State Transport Initiatives
Solar Street Lighting	Low	Medium	MNRE Solar Programs
Lakhtar Fort Conservation	Medium	Medium	Heritage Conservation & Tourism Policies

11 Conclusion and Summary

The research on "Enhancing Resource Utilisation for Sustainable Rural Development through Smart Infrastructure Planning: A Case of Lakhtar, Surendranagar." illustrates that sustainable transformation of rural settlements is achievable through strategic, locally adaptive, and technology-integrated interventions. The suggested proposals—roads, smart bus stops, solar street lighting, RO water plant, solid waste management, biogas generation, Fort conservation, and lakefront development—can be implemented using readily available state resources and technologies. This ensures that the research and its suggested proposed framework align with Gujarat's policy and market feasibility.

If the proposals are applied systematically, it will redefine Lakhtar's development trajectory in the following ways:

1. The upgraded road network and smart bus stop intervention will make it easy for the commuters and villagers to access schools, markets, and healthcare centers, and also reduce the traffic congestion at the main approach road.

2. Solar-powered streetlights, bus stops, and community biogas plants will collectively reduce dependence on traditional electricity sources and fossil fuels. This is a sustainable solution that will lower operational costs and promote carbon neutrality in Lakhtar village.

3. The Motisar Lakefront development and Lakhtar Fort wall conservation will enhance the livelihood and create opportunities for occupation and economy through tourism and small-scale enterprises. It will surely add more to the beauty of the village. The green buffers and sustainable water management will improve the village's climate resilience.

4. The villagers will be able to access adequate safe drinking water by implementing an RO plant. A clean and healthy environment can be achieved by practicing proper waste segregation and disposal systems.

5. All proposed technologies and materials are aligned with MNRE and CPCB guidelines, which can be a reference to other similar villages of the state. The integration of physical, social, and digital infrastructure will ensure scalability within the National Rurban Mission and Digital India frameworks.

If implemented, these proposals can transform Lakhtar into a self-sustaining, digitally connected, and environmentally responsible smart village. Lakhtar will have an improved quality of life, diversified livelihoods, and a resilient local economy. This can happen only by field-oriented research methods and strategic infrastructural planning. Such efforts can bridge the gap between rural and urban development goals, contributing to sustainable development goals [6, 7, 9, 11, and 13].

Acknowledgements

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I am deeply indebted to the Gram Panchayat of Lakhtar, the Talati and the Sarpanch of the village for their cooperation and assistance during my field visits. Their local knowledge and insights were crucial for understanding the context of my research.

This research has been a truly rewarding experience, I am grateful to everyone who played a part in it.

Declaration of Generative AI in Scientific Writing

We use OpenAI's ChatGPT and Grammarly to assist in structuring and language editing. All ideas, analysis, and conclusions are my original contributions. The AI tool was not used to generate data or interpretations.

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