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Achieving Low Carbon Transformation in Developing Urban Periphery: Case of Dehu

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***Abstract*— This research examines the challenges and opportunities for achieving low-carbon transformation in Dehu, a historically and culturally significant town in Maharashtra's Pune district. As a critical connector between Pune city and the Chakan Industrial Corporation, Dehu faces rapid urbanization pressures that threaten its environmental sustainability and cultural heritage. This study analyses current environmental challenges, identifies strategic opportunities through SWOT analysis, and proposes comprehensive recommendations aligned with India's Long-Term Low-Carbon Development Strategy and relevant SDGs. The research emphasizes the integration of sustainable urban planning, renewable energy adoption, community engagement, and cultural preservation to achieve low-carbon development while maintaining Dehu's unique identity as the birthplace of Sant Tukaram.**

***Keywords*—Low-Carbon development, Sustainable Urbanization, Cultural Preservation, Dehu, Urban Periphery, SDGs**

I. INTRODUCTION

India's commitment to achieving net-zero emissions by 2070 necessitates comprehensive low-carbon development strategies, particularly in rapidly urbanizing peripheral areas. Dehu, a small town in Maharashtra's Pune district, presents a unique case study for sustainable urban transformation. Renowned as the birthplace of Sant Tukaram, a key figure in the Bhakti movement, Dehu holds immense historical, cultural, and religious significance while serving as a strategic connector between Pune city and the Chakan Industrial Area.

This research investigates the potential for low-carbon transformation in Dehu, addressing the critical balance between economic development, cultural preservation, and environmental sustainability. The study aims to provide actionable strategies that can serve as a model for similar urban periphery areas across India.

II. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

A. Low-Carbon Development Concepts

Low-carbon development represents a paradigm shift toward sustainable growth that minimizes greenhouse gas emissions while promoting economic prosperity and social well-being [1]. The concept encompasses energy transition, sustainable mobility, urban sustainability, and industrial decarbonization [2]. There has always been an emphasize on the importance of evaluating low-carbon development quality in cities and identifying implementation barriers [3].

B. Policy Framework

India's Long-Term Low-Carbon Development Strategy (2022) outlines key areas for transformation:

- Expanding renewables and strengthening the grid
- Developing integrated, efficient, inclusive, low-carbon transport systems
- Promoting adaptation in urban design and energy-efficient buildings
- Encouraging low-carbon municipal service delivery
- Supporting green spaces and carbon sequestration initiatives

III. STUDY AREA: DEHU TOWN PROFILE

A. Historical and Cultural Significance

Dehu's identity is intrinsically linked to Sant Tukaram, whose Abhangas form the foundation of Marathi literature and spirituality [4]. The town houses the main temple located on the Indrayani River and the new Gatha Mandir dedicated to Tukaram's Abhangas. These religious sites attract significant pilgrimage tourism, particularly during the annual Wari pilgrimage to Pandharpur, which continues to be one of India's most significant spiritual journeys with over 800,000 participants annually [5].

B. Geographic and Strategic Importance

Dehu's strategic geographic positioning establishes it as a vital connector between the metropolitan center of Pune and the thriving Chakan Industrial Area [6]. The town benefits from excellent road connectivity through the Pune-Nashik Highway (NH 60) and the dedicated Dehu Road-Chakan corridor, which facilitates seamless transportation of raw materials, finished goods, and human resources between these economic hubs [7]. This transportation network is further strengthened by the proximity to Dehu Road railway station, which integrates the region into Maharashtra's broader rail infrastructure, enabling efficient movement of both passengers and freight across the state.

The economic significance of Dehu's location cannot be overstated, as it functions as a crucial transit point that supports complex logistics and supply chain operations connecting Pune's urban commercial center with Chakan's industrial complexes [8]. Located approximately 20 Kms.

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from the Chakan Maharashtra Industrial Development Corporation (MIDC), Dehu provides strategic access to one of India's most significant automotive manufacturing hubs, which houses major industrial giants including Tata Motors, Bajaj Auto, and Mercedes-Benz, along with numerous ancillary industries that support the automotive ecosystem [9].

IV. METHODOLOGY

This study employs a mixed-methods approach combining:

- Field surveys and observational studies
- SWOT analysis framework
- Policy analysis aligned with national and international frameworks
- Case study analysis of best practices (Masdar City, UAE)
- Stakeholder consultation and community engagement assessment

V. CURRENT CHALLENGES AND ISSUES

Fig. 1. Connectivity between Dehu town and Pune City wrt Pune Airport

Fig. 2. Palkhi Route during the annual Wari between Dehu and Pune City

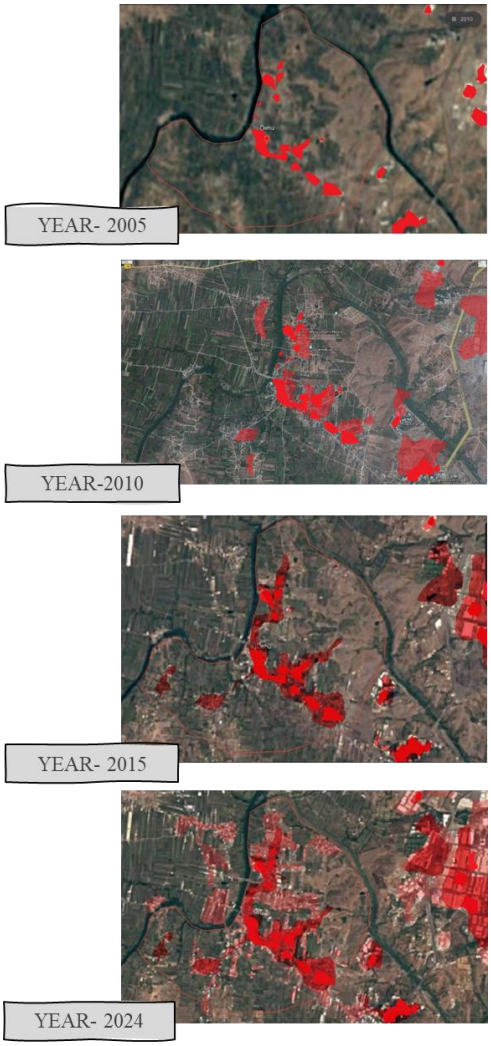

Fig.3. Dehu Growth Pattern as per sattelite imagery from 2005 -2024
Source: https://www.google.com/earth/about/versions

A. Rapid Urbanization impacts

The study identifies several critical challenges resulting from unplanned urban expansion that threaten both environmental sustainability and community well-being. Environmental degradation has emerged as a primary concern, manifesting through significantly increased carbon emissions from intensified vehicular traffic and expanded industrial activities [4]. The town faces severe air and water pollution challenges, with the historically pristine Indrayani River bearing the brunt of contamination from untreated sewage discharge and industrial waste disposal. This pollution has led to widespread eutrophication of water bodies throughout the river system, creating dead zones that threaten aquatic ecosystems and compromise the water quality that local communities depend upon for daily needs and religious practices.

The replacement of natural landscapes with concrete infrastructure has created pronounced urban heat island effects, where local temperatures exceed human comfort levels and dramatically increase energy demands for cooling systems [10]. Research indicates that urbanization alone has led to an overall 60% enhancement in warming in Indian cities, with medium-sized cities experiencing particularly intense heat

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stress effects [11]. Simultaneously, unregulated construction activities have disrupted natural drainage patterns, leading to accelerated soil degradation and heightened vulnerability to seasonal flooding, which poses risks to both existing structures and newly developed areas.

Infrastructure stress has become increasingly apparent as existing systems struggle to accommodate growing population demands and the substantial influx of religious tourism. The town's waste management capabilities have proven inadequate for current needs, resulting in improper disposal practices that further exacerbate environmental degradation [12]. Progressive loss of green cover has reduced the town's natural capacity for carbon sequestration and climate regulation, while insufficient water and sanitation services create public health risks for both permanent residents and the thousands of pilgrims who visit annually.

Cultural Identity Threats were observed during the field visits such as:

- Loss of traditional architectural styles in new developments
- Pressure on religious and cultural spaces
- Unauthorized encroachments affecting sacred areas

B. Specific observational challenges

- Field surveys revealed immediate issues requiring attention:
- Unauthorized parking reducing effective road width
- Absence of adequate toilet facilities leading to unhygienic conditions
- Insufficient drinking water facilities for tourists and devotees
- Hawkers occupying pedestrian pathways
- Inadequate Road sections for mixed traffic (vehicular, bicycle, pedestrian)
- Sewage and industrial waste disposal in Indrayani River

VI. SWOT ANALYSIS

A. Strengths

Dehu's most significant asset lies in its extraordinary rich cultural heritage, which positions the town as one of Maharashtra's most important pilgrimage centers and spiritual destinations. This deep-rooted religious significance, centered around the legacy of Sant Tukaram and the annual Wari pilgrimage tradition, creates a powerful sense of community identity and social cohesion that transcends economic and social boundaries [13]. The town's spiritual magnetism consistently attracts thousands of devotees and cultural tourists, generating substantial economic opportunities while reinforcing traditional values and practices that have sustained the community for centuries.

The town's strategic geographic location provides exceptional access to employment opportunities and business partnerships through its proximity to the Chakan Maharashtra Industrial Development Corporation and expanding information technology parks. This positioning offers residents access to a rapidly growing pool of skilled employment in diverse sectors including manufacturing, information technology services, logistics, and supporting industries, while simultaneously attracting potential investors and entrepreneurs seeking locations that combine industrial access with cultural authenticity.

B. Weaknesses

Despite its cultural and geographic advantages, Dehu faces significant infrastructure limitations that constrain its development potential and quality of life. The town lacks comprehensive healthcare facilities capable of serving both its permanent population and the substantial influx of religious tourists, particularly during major festivals and pilgrimage seasons. Sanitation infrastructure remains inadequate, with sewage treatment and waste management systems unable to handle current demands, let alone accommodate future growth projections.

Public transportation systems are virtually non-existent, forcing residents to rely on private vehicles or informal transportation options that contribute to traffic congestion and air pollution [14]. The combination of limited parking facilities and narrow roadways creates chronic congestion problems that are particularly acute near markets, religious sites, and other high-activity areas. These infrastructure limitations not only hinder daily life for residents but also impede emergency services access and overall economic development potential.

C. Oppurtunities

The ongoing development of surrounding industrial and information technology hubs presents unprecedented opportunities for economic growth and improved living standards in Dehu. Migration patterns driven by employment opportunities in nearby Chakan industries are bringing educated, skilled workers to the region, creating demand for improved housing, services, and amenities. This influx of new residents with disposable income can stimulate local commerce and create markets for goods and services that previously might not have been viable in the smaller traditional community.

Infrastructure development investments in the broader Maharashtra Industrial Development Corporation region are likely to catalyze improvements in Dehu's own infrastructure systems, including road networks, utilities, healthcare facilities, and educational institutions. The growing recognition of cultural heritage tourism as an economic driver presents opportunities to develop sustainable tourism initiatives that can generate revenue while preserving and celebrating the town's unique spiritual and cultural assets [15].

D. Threats

The proximity to rapid industrial development poses significant risks to Dehu's agricultural land base, as economic pressures increasingly favour conversion of productive farmland to residential and commercial uses. This transformation threatens local food security, traditional livelihoods, and the rural character that has historically defined much of the town's identity. The loss of agricultural land also eliminates important carbon sequestration capacity and increases dependence on external food sources, compromising both environmental sustainability and economic resilience.

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Increased commuting between Dehu and nearby employment centers is generating serious traffic congestion that degrades air quality and significantly impacts residents' quality of life. Without comprehensive public transportation solutions and effective traffic management strategies, this congestion will likely worsen as development pressures intensify, potentially making the town less attractive to both residents and visitors while increasing the environmental costs of economic development.

VII. SDG ALIGNMENT AND LOW CARBON DEVELOPMENT

This research framework strategically aligns with seven key Sustainable Development Goals to address Dehu's sustainable transition challenges.

SDG 3 (Good Health and Wellbeing) tackles inadequate healthcare infrastructure and sanitation systems affecting residents and religious tourists [16].

SDG 6 (Clean Water and Sanitation) addresses Indrayani River contamination and insufficient sanitation facilities requiring comprehensive wastewater treatment and restoration programs [17].

SDG 7 (Affordable and Clean Energy) leverages Dehu's geographic advantages for renewable energy adoption, particularly solar installations that can demonstrate sustainable practices to pilgrimage visitors [18].

SDG 9 (Industry, Innovation, and Infrastructure) focuses on developing resilient infrastructure that preserves cultural heritage while supporting economic development [19].

SDG 11 (Sustainable Cities and Communities) represents the core challenge of maintaining cultural authenticity while embracing modern sustainability features through integrated planning approaches [20].

SDG 12 (Responsible Consumption and Production) emphasizes circular economy approaches for waste management and resource efficiency [21].

Finally, SDG 17 (Partnerships for the Goals) recognizes that success requires extensive multi-stakeholder collaboration across government, private sector, and civil society organizations to mobilize diverse resources for comprehensive transformation.

VIII. STRATEGIC RECOMMENDATIONS

A. Sustainable Urban Development Framework for Pilgrimage Towns

Sustainable transformation of pilgrimage towns requires integrated approaches combining urban planning, infrastructure development, and community engagement. Effective zoning with green infrastructure provides essential ecosystem services while comprehensive building codes prioritize energy efficiency and renewable energy integration [22]. Transportation systems must accommodate seasonal pilgrimage variations through user-centric design and public transit enhancement to reduce carbon emissions [23].

Infrastructure development should focus on healthy streets with proper accessibility features, strategic sanitation facilities, and comprehensive waste management systems capable of handling pilgrimage season demands [24]. Renewable energy initiatives, including solar installations and smart grid integration, enable energy transition while resource management through waste segregation and circular economy practices supports environmental sustainability [25].

Low-carbon mobility solutions require electric vehicle adoption support, non-motorized transport infrastructure, and integrated public transportation systems with intelligent traffic management [26]. Community engagement through inclusive decision-making processes and cultural preservation strategies ensures development reflects local values while educational campaigns promote sustainable practices aligned with traditional beliefs [27].

IX. CASE STUDY ANALYSIS: MASDAR CITY, UAE

Masdar City in the United Arab Emirates stands out as a pioneering example of zero-carbon and zero-waste urban development. It offers numerous insights that can inform the sustainable transformation of Dehu. As an innovation and research hub, Masdar City has successfully integrated renewable energy research and clean technology development. The city actively supports cleantech startups by offering both funding and access to expert knowledge, fostering an environment conducive to innovation. Additionally, Masdar incorporates advanced educational technologies, including the use of metahuman guides, and features LEED Platinum-certified residential and office spaces that exemplify energy-efficient design.

In terms of transportation, Masdar City emphasizes sustainable and smart mobility. Its Personal Rapid Transit (PRT) system utilizes driverless electric vehicles, and the city also deploys autonomous shuttles to promote efficient, clean movement. The pedestrian-friendly urban design encourages walking and cycling, reducing dependency on personal motor vehicles and supporting point-to-point convenience. The city's environmental integration strategies are equally noteworthy. It features a central park with horizontal gardens and innovative water collection systems, as well as traditional falaj-style water channels that ensure efficient water management. Public play areas utilize equipment powered by human movement, and the overall architectural design incorporates natural ventilation and cooling systems, reducing the need for mechanical air conditioning.

X. IMPLEMENTATION FRAMEWORK FOR LOW-CARBON URBAN DEVELOPMENT

The successful implementation of a low-carbon urban development strategy in Dehu requires a comprehensive and multi-dimensional approach that integrates robust policy frameworks, innovative regulatory measures, and adaptive management systems. Contemporary research demonstrates that effective low-carbon transitions in urban peripheral areas necessitate the creation of context-specific local climate action plans that align with broader regional and national sustainability objectives [28]. In the case of Dehu, these plans must be meticulously tailored to address the settlement's unique environmental characteristics, socioeconomic dynamics, and cultural heritage significance while maintaining coherence with Maharashtra's overarching climate goals and India's national commitments under the Paris Agreement.

The policy architecture for Dehu's transformation should incorporate sophisticated incentive structures that encourage widespread adoption of sustainable practices across all sectors of the local economy. Recent studies highlight the critical

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importance of fiscal instruments, including targeted tax benefits and strategic subsidies, in accelerating the deployment of green technologies and promoting environmentally conscious behaviors among residents and businesses [29]. These financial mechanisms must be complemented by a comprehensive regulatory framework that establishes mandatory building codes prioritizing energy efficiency, implements rigorous environmental impact assessment protocols for all development projects, and introduces zoning regulations specifically designed to protect Dehu's invaluable cultural heritage assets and sensitive environmental areas.

The establishment of public-private partnerships emerges as a particularly crucial element in financing and implementing sustainable infrastructure projects effectively, as demonstrated by successful urban sustainability initiatives across developing countries [30]. These collaborative arrangements can leverage private sector expertise and capital while ensuring public oversight and community benefit maximization. Furthermore, the implementation strategy must incorporate a robust monitoring and evaluation system that tracks the performance of implemented projects through quantitative metrics, conducts regular assessments of environmental impact reduction using standardized methodologies, and measures progress toward specific carbon footprint reduction goals through transparent reporting mechanisms that foster public trust and accountability.

An adaptive management approach represents a fundamental requirement for long-term success, as urban sustainability challenges are inherently dynamic and require continuous strategy refinement based on empirical performance data and evolving stakeholder needs [31]. This iterative process must integrate regular policy reviews, stakeholder feedback incorporation, and knowledge sharing mechanisms with other urban peripheral areas facing similar sustainability challenges. The expected outcomes from this comprehensive implementation framework are substantial and multifaceted, encompassing significant environmental benefits such as measurable carbon emission reductions, improved air and water quality, enhanced biodiversity conservation through increased green cover, and strengthened climate resilience with reduced flood risks.

Economic benefits are equally compelling, including job creation in renewable energy and sustainable construction sectors, increased property values through improved infrastructure, enhanced tourism revenue generation, and reduced long-term infrastructure maintenance costs due to durable, sustainable system implementation [32]. Social benefits manifest through improved public health outcomes resulting from pollution reduction and enhanced sanitation services, elevated quality of life for residents and visitors through better infrastructure and preserved cultural heritage, and strengthened social cohesion through meaningful community engagement initiatives that foster shared responsibility and pride in Dehu's sustainable future.

XI. IMPLEMENTATION CHALLENGES

However, implementation challenges must be realistically acknowledged and systematically addressed. Financial constraints remain a persistent obstacle, particularly for comprehensive infrastructure development projects, while coordination difficulties among different governmental levels and agencies can significantly impede progress [33].

Resistance from established stakeholders who are apprehensive about change, coupled with the critical need for technical capacity building to equip local personnel with necessary implementation skills, represents additional hurdles that require strategic management. Despite these challenges, Dehu's strategic location connecting Pune city and Chakan Industrial Area, combined with its rich spiritual significance and cultural heritage, creates unique opportunities for sustainable development that can serve as a replicable model for similar urban peripheral areas across India and the broader developing world, contributing meaningfully to national and global sustainability objectives while preserving the authentic character that defines Dehu's distinctive identity.

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