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Exploring the Potential of Neighbourhood Approach to Low Carbon Development in India

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Highlights

- A top-down approach for sectors and a bottom-up approach to integrating local knowledge and indigenous measures are vital for sustainable low-carbon development.
- Among 128 Indian cities analyzed, only 10 have comprehensive sectoral approaches for city climate action.
- Adopt performance-based codes for local area plans, replacing conventional zoning and form-based codes for climate action.
- Low-carbon design strategies are identified from urban design concepts, which can be used in design for achieving low-carbon development at the neighborhood scale.

Abstract

India has committed to addressing climate change through its Nationally Determined Contributions (NDC) and has set a target of achieving net-zero emissions by 2070. The National Action Plan on Climate Change (NAPCC) Low carbon strategies for Long-Term Low Emission Development Strategy (LT-LEDS) and State Action Plans on Climate Change (SAPCCs) provide a framework for addressing climate change. However, there is a lack of emphasis on climate change action in the development plans of urban local bodies. This research aims to extend the findings from government documents at the city scale that are aligned with SAPCCs in promoting low-carbon development and explore how urban design can be utilized by local governments to integrate climate action plans into local area development plans. The study analyses city climate-related documents from 128 cities in India and proposes various urban design interventions to achieve low-carbon development goals.

Keywords: Low carbon development, Urban Design, City climate action plans, Local area plan', Performance-based code.

Introduction

Cities contribute significantly to global warming. While they constitute less than 2% of the planet's surface area, they are responsible for approximately 60% of global greenhouse gas emissions and consume 78% of global energy [1]. India's growing economy and large population will result in a significant increase in the number of cities with over 1 million residents, expanding from 42 to 68 [2]. Therefore, India's growth trajectory is crucial for the accomplishment of the world's sustainable development goals. As stated in the United Nations Framework Convention on Climate Change (UNFCCC), India is committed to tackling the issue with strict adherence to multilateralism based on equality and the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC). India has pledged to address climate change through Nationally Determined Contributions (NDC) to ensure long-term growth and development towards net zero by 2070 [3].

Based on NDC, India's National Action Plan on Climate Change (NAPCC) aims to mitigate and adapt to climate change. One of the eight missions of India's National Climate Action Plan is to deploy appropriate technologies for the adaptation and mitigation of greenhouse gas emissions [4]. In alignment with NAPCCs, 28 States and 6 Union Territories have

prepared their State Action Plan on Climate Change (SAPCCs) as shown in Table 1. The SAPCCs provide a mapping of regional climate vulnerability, examine future projections, arrive at sectoral implications, and frame actionable strategies for combating climate change. Hence, each city can have a climate action plan drawn out per the SAPCCSm [5].

A major part of India's emissions is from cities, with buildings within cities accounting for more than 40% of India's total energy consumption. As mentioned in India's Long-term low carbon development strategy (LT-LEDS) [6], this presents a unique chance to advance the ambitious climate policy by empowering the local governments. This is especially significant in the case of India, where there are five distinct climatic zones and climate types across the country [7]. The Urban Local bodies are poised to possess valuable contextual knowledge regarding the environment, infrastructure, and social issues unique to their respective localities. As per the 74th amendment of the Constitution of India in 1992, urban local bodies are recognized as institutions of self-governance at the local level; however, these bodies have little mandate to combat climate change [8]. Moreover, a study undertaken by Khosla and Bhardwaj revealed that climate change rarely features in the development plans of these bodies [9].

The purpose of this research is to study the government's various climate change-related documents issued in alignment with SAPCC and assess their efficacy in advocating for low-carbon development. The paper also looks at how urban design can be used as a means for local governments to institutionalize a framework for implementing climate action plans into Local Area Development Plans (LAD).

Literature review

The literature review offers a concise overview of different actors involved in climate governance, spanning from the international level to local bodies, and highlights India's endeavors towards achieving low carbon development.

The Kyoto Protocol, implemented in 2005, serves as an initial measure to tackle climate change by setting targets for industrialized nations and transitioning economies to limit and decrease greenhouse gas (GHG) emissions based on agreed-upon individual objectives under the United Nations Framework Convention on Climate Change [10]. Later, the 2015 Paris Agreement became the first global agreement on climate change that includes policy commitments for all nations. It is a combination of bottom-up and top-down approaches to global climate governance [11], [12]. Additionally, a legally enforceable climate change accord that seeks to keep global warming below 2°C, preferably 1.5°C. However, due to the severe climate impact consequences associated with exceeding the 1.5°C threshold, greenhouse gas emissions will peak by 2025 and decrease by 43 percent within 2030 to accomplish this goal.

NDCs are the specific national climate action plans that each government has been submitting since 2020. Countries describe their proposed efforts to reduce greenhouse gas emissions to accomplish the goals of the Paris Agreement in these plans. Additionally, they communicate strategies to enhance adaptability and resilience to climate change impacts. To establish a more comprehensive context for efforts focused on NDCs, countries are instructed to develop and submit long-term low greenhouse gas emission development strategies (LT-LEDS). It contains a country's long-term planning and development priorities, providing a vision and direction for future development [13].

To implement the commitments made through NDC, countries use an array of governance mechanisms to design and implement climate policies and establish time-bound targets for carbon or climate neutrality. According to Huovila et al., there is limited research that defines a "carbon-neutral city." However, as the scope of city emissions is within geographical, temporal, activity, or life cycle system boundaries, terms such as zero carbon, low-carbon, or carbon-neutral city are addressed through a proposal of three hierarchical emissions categories. These categories are internal emissions based on the geographical boundary, external emissions directly caused by core municipal activities, and internal or external emissions due to non-core activities [14], [15]. Each hierarchical category denotes a distinct carbon management approach. This approach of the categories can be broadly stated as - zero carbon aims at elimination, low-carbon aims at minimizing, and carbon-neutral city aims at balancing the carbon emissions [14]. In this context, low-carbon development emerges as a novel approach that strives to minimize carbon dioxide emissions without compromising economic growth and well-being [16].

Neighbourhoods are building blocks of our cities [17]. It extends beyond a single building by including open spaces and urban networks giving a demonstration of urban reality. It can be considered as a target for testing concrete interventions within a reasonable time frame [18],[19]. It is in neighbourhoods that climate action becomes tangible and can engage community participation involving individuals who are environmentally responsible through their actions [20], [21].

A neighbourhood, being the basic arena to create a sustainable environment, becomes the beginning point for the use of low-carbon strategies and technologies to address climate change, promoting the development of a low-carbon city. The underlying concept of a low-carbon neighbourhood forms when viewed from a perspective of low emission. A balance between carbon source control and carbon sink expansion [22]. According to wang et al. 2016, the five most important aspects of low-carbon neighbourhood assessment are layout planning, traffic planning, architecture planning and design, environment planning, municipal engineering planning, and construction management. These can be broadly linked with the parameters of the climate-smart city action framework for finding the best available urban design concepts, policies, design strategies, and smart goals/benchmarks that can cater to a low-carbon neighbourhood.

Clause 2.3 of the LT-LEDS document emphasizes the promotion of adaptation in urban design, energy and material efficiency in buildings, and sustainable urbanization. Within this clause, sub-clause 2.3.2.1 focuses on mainstreaming adaptation measures in urban planning and enhancing energy and resource efficiency through guidelines, policies, and bylaws. Sub-clause 2.3.2.2 highlights the importance of promoting climate-responsive and resilient building design, construction, and operation. Lastly, subclause 2.3.2.3 emphasizes the need to promote low-carbon municipal service delivery by efficiently managing water, solid waste, and liquid waste.

India's long-term low-carbon strategy development plan suggests a framework for cities known as the City Climate Action Plan (CCAP) [23]. The CCAP framework is designed to help cities develop a climate action plan based on their current emissions profile, identify potential mitigation measures, and develop strategies to transition to a low-carbon pathway. The framework includes key components such as conducting a greenhouse gas inventory, assessing vulnerability to climate change impacts, setting emission reduction targets, and implementing a range of measures in sectors such as energy, transportation, waste management, and urban planning. The CCAP aims to provide a systematic approach for cities to address climate change and promote sustainable development at the local level.

The Ministry of Housing and Urban Affairs has introduced the Climate Smart Cities Assessment Framework (CSCAF) [24] to facilitate a comprehensive evaluation and benchmarking of urban development in terms of climate change considerations. This framework is designed to align with the National Mission on Sustainable Habitat, NDC, Sustainable Development Goals, and Sendai Framework for disaster management. It serves as a valuable resource for cities to guide their investments, demonstrate tangible climate actions, and monitor outcomes. The CSCAF encompasses five key thematic areas: urban planning, green cover, and biodiversity; energy and green buildings; mobility and air quality; water management; and waste management. By utilizing this framework, cities can gain insights into their current climate performance, identify areas for improvement, and develop a roadmap for integrating climate change considerations into urban planning. The CSCAF empowers cities to make informed decisions, enhance their resilience to climate impacts, and contribute to the overall goal of low-carbon development.

In India, local area planning is conducted through a multi-tiered system involving the central government, state governments, and local bodies. The process encompasses several stages and stakeholders, although the approach may vary slightly across different states and regions. Here is a concise overview of how local area planning is typically carried out in India.

Through the 73rd and 74th Amendments, the constitutional framework grants authority to local self-government bodies, namely Urban Local Bodies (ULBs) and Panchayats, to plan and manage development activities within their jurisdictions. Urban planning in cities is primarily guided by development plans such as master plans, city action Plans, and local area plans, which establish the groundwork for land use, infrastructure development, environmental conservation, and social amenities [25]. Therefore, local Climate action plans need to be contextual and tailored to the specific region, climate, geography, and local conditions. The impacts of climate change can vary significantly across different areas, and therefore, the strategies and measures included in climate action plans should be designed to address the unique challenges and opportunities of each location.

Methodology

This study looks at the issue of low-carbon development in two sections. To begin with, the study analyses the action plan undertaken by 126 cities that participated in the CCAP assessment. Mumbai and Hyderabad tier-1 cities are also considered as part of this study, adding up to 128 city samples in total. Subsequently, the study presents various techniques that may be adopted by the city to achieve its target through urban design interventions. Since the goal of the country is to reduce GHG emissions, the adoption of various urban design interventions is expected to help cities reduce carbon emissions through a bottom-up approach. The Climate Action Plans considered for this study provide a detailed framework for measuring, tracking, and reducing existing and potential greenhouse gas emissions and other climate-related events. The city corporations or municipalities consider these action plans as a guide to address the impact of climate change on their environment and communities.

About the analysis of action plans undertaken by cities, it is important to note that a city climate action plan is generally prepared with differences in purpose, methodology, structure, and scope. Investigating the various city climate action plans revealed such differences. For example, the content of these plans varies, with some plans encompassing comprehensive climate action strategies that encompass greenhouse gas (GHG) assessments and low-carbon development strategies. On the other hand, certain plans focus specifically on low-carbon development roadmaps, outlining pathways for reducing emissions in energy-intensive sectors. Additionally, some climate action plans are integrated within broader documents that address climate resilience, including elements like GHG emission inventories and vulnerability assessments. Furthermore, sectoral plans also exist that target specific aspects of climate change, such as clean air action plans, district environment plans for waste management, and emergency response plans for events like heatwaves and flooding, referred to as disaster management plans and heatwave action plans.

The study sample consists of 52 metropolitan cities (tier 1), 34 large cities (tier 2), 33 medium cities, and 9 small towns. The focus of this study is on tier-1 metropolitan cities and tier-2 large cities and towns within the selected city sample.

The study took advantage of online climate action plans updated by the city and contacted the respective city representatives in cases where additional information or clarification was needed. The study assumes that cities have an online presence of their climate action plan and considers only those cities where a plan or policy was available. These action plans may be officially adopted by the municipal government or simply acknowledged; they may be legally binding or non-binding to the city administration. The study reveals that there are five types of climate action plans. The study develops the typology of climate action plans that serve as a framework for analysis, as presented in Table 1. The action plans are categorized based on approaches used by climate action plans, such as covering major energy-intensive sectors, the pattern followed by different organizations while preparing the plan, and the assessment of GHG emissions across sectors to minimize emission inventory.

Type A: In this category, the study includes city climate action plans relevant for the entire city for a 'climate change action plan' or 'climate change and environment action plan.' It includes mitigation and adaptation actions across sectoral themes, such as Energy and Buildings, Sustainable Mobility, Sustainable Waste Management, Air Quality, and Waste Resource Management. These plans include climate change impact on a multi-sectoral level, GHG emissions inventory assessment, assessment of existing policies on climate change developed by the urban/municipal authority, adaptation and mitigation actions for all sectors, and framework for monitoring and evaluation with an institutional setup, e.g., Ahmedabad Climate Change and Environment Action Plan and Mumbai Climate Action Plan.

Table 1: Typology of city scale climate action plans

Comprehensive (A)	**Partial climate strategy approach (B)**	**Mainstreamed and inclusive (C)**	**Partial GHG emissions inventory, stand-alone (D)**	**Sectoral (E)**
City Climate Action Plan of the urban authority that comprehensively (multiple sectors) addresses strategies, including both mitigation adaptation actions to achieve or adapt to low carbon emission development. The CCAP shall include baseline vulnerability assessment, GHG emissions inventory assessment, and climate action plan to mitigate GHG emissions and adapt to climate-prone disasters.	Climate Resilient Plans of the urban authority that addresses (multiple sectors) in terms of adaptation actions only. The climate resilient plan shall include climate risk and impact assessment, connecting climate profile to city development plans and strategies to adapt to identified climate risks. These plans do not include GHG inventory and reduction targets to mitigate the effects of climate change.	Low Carbon Development Plans cover aspects of disaster management plans, strategic low carbon development pathways across buildings, energy, mobility, water, and waste across all sectors. This typology also focuses on ward level or neighbourhood level institutional framework to achieve low carbon development	Plans covering aspects of partial GHG emissions inventory assessment for 3 or fewer sectors and impacts such as heat waves	Climate plan for parts of the municipal climate change mitigation operations, such as waste management, air pollution, and heat wave adaptation action plans
Example: City Climate Action Plan, District Climate Action Plan, Climate Change and Environment Action Plan	Example: Climate Resilient Plan	Example: Low carbon development plan	Example: Low Carbon Mobility Plan	Example: Heat Action Plan, Action Plan for Clean Air, District Environment Plan

Type B: In this category, the study includes climate resilient plans on 'city climate resilience plan' or 'climate resilient strategy', and includes adaptation measures majorly to cope up with the emerging climate change scenarios. These plans assess climate risks, vulnerability, and capacity of cities on the basis of dynamic factors that could affect the city, such as urbanization, impacts on physical, economic, and social infrastructures, creating awareness about climate risk from the ward level, and proposes strategies to adapt to the effect of climate change. In this case, strategies in terms of energy efficiency, solid waste management, wastewater treatment, natural disaster management, capacity building to stakeholders, and health monitoring systems are proposed as strategies in all the plans. These plans do not exclusively include GHG inventory and reduction targets to mitigate climate change effects, e.g., Climate Resilient Climate Action Plan - Udaipur and District Climate Resilience Plan - Jhansi.

Type C: This category includes low-carbon development plans. They are structured to identify, plan, and implement measures for achieving low GHG emissions across multiple sectors such as buildings and built environment, mobility, waste management, land use, and energy. These plans also integrate resilient measures to adapt to climate change impacts. They follow a bottom-up approach, starting from ward-level action plans to mobilize and implement low-carbon development strategies, e.g., Low Carbon Development Scenario Bhopal 2035

Type D: The focus in this type is partially on one sector, such as mobility, to curb GHG emissions. The plans focus on public bicycle sharing programs, amendments to building regulations such as e-vehicle charging facilities, e-mobility plans, and intelligent transportation systems to provide safe, universal, and easy mobility solutions for all. These plans help mitigate climate change actions by reducing the need for fuel-based motorized vehicles and increasing awareness of non-motorized transportation, e.g., Low Carbon Mobility Plan - Visakhapatnam and E-mobility Plan - Bhubaneswar.

Type E: Aspects of climate change mitigation strategies are observed in the District Environment Plan and Action Plan for air pollution control. These plans focus on waste management strategies and air pollution control. This compiled database of the cities is presented in Table 2. This gathered information includes climate action plans, climate resilience plans, low carbon development plans, low carbon mobility plans, and district environment plans. The study provides a systematic and objective approach to analyze and compare city climate plans, to identify commonalities, assess trends, and evaluate the effectiveness of these plans in addressing climate change, e.g., District Environment Plan - Raipur, Action Plan for Clean Air - Guntur, Heat Action Plan – Bhubaneswar.

In the above-mentioned five typologies, the components in types B, C, and D can be found in the type A plan. Type A provides a detailed and comprehensive understanding of mitigation and adaptation strategies across all sectors and also includes vulnerability assessment and low-carbon development pathways to reduce GHG emissions. For example, the Mumbai City Climate Action Plan includes city-wide mitigation targets, GHG scenarios, sectoral strategies as found in type D and C, and assessment of climate risk and vulnerabilities as seen in type B, sectoral plans, and institutional structures.

Table 2: Number of climate action plans across 128 cities.

States	Cities	Type A	Type B	Type C	Type D	Type E	Action plan unavailable
	N	N	N	N	N	N	N
Andhra Pradesh	6		1		1	4	0
Arunachal Pradesh	2						2
Assam	1		1				0
Bihar	4			1		2	1
Chattisgarh	3					1	2
Goa*	1		1		1		0*
Gujarat	7	2	3			1	1
Haryana	3			1		1	1
Himachal Pradesh	6		1	1		2	2
Jharkhand	2					2	0
Karnataka	9			1		5	3
Kerala	2					2	0
Madhya Pradesh*	7	2	1	1		4	0*
Maharashtra	14	3	3	1		4	3
Manipur	1						1
Meghalaya	1						1
Mizoram	1				1		0
Nagaland	1						1
Odisha*	3				1	3	0*
Punjab	4					3	1
Rajasthan	5		1		1	3	0
Sikkim	2						2
Tamil Nadu	11	1	3	1		2	4
Telangana	3					3	0
Tripura	1		1				0
Uttarakhand	1					1	0

Uttar Pradesh	14		1			6	7
West Bengal	3		1	1		1	0
Andaman and Nicobar Islands	1						1
Chandigarh	1			1			0
Dadra and Nagar Haveli and Diu and Daman**	2					1	1
NCT of Delhi	1	1					0
Jammu and Kashmir	2						2
Ladakh**	2					1	1
Lakshadweep	1						1
Puducherry	1	1					0
Total	128	10 (7.81%)	18 (14.06%)	9 (7.03%)	5 (3.91%)	52 (40.63%)	38 (29.68%)

Note: **Panaji has two types of plans: (1) Panaji-Low Carbon Action Plan for Urban Freight and (2) PanajiClimate Resilient Infrastructure Services*

**Bhopal has two types of plans: (1) Low Carbon Development Scenario Bhopal 2035 and (2) Climate Change and Environment Action Plan of Bhopal District*

**Bhubaneswar has two types of plans: (1) Bhubaneshwar E-mobility Plan and (2) Heat Action Plan*

***Ladakh, Dadra & Nagar Haveli, and Diu & Daman don't have a SAPCC.*

The sectors mentioned in the tables above, i.e., the Type A, B, C, D, and E plans, were then compared with the City Climate Action Plan (CCAP) framework to identify the plans that can be recommended for local area planning. The findings from these comparisons revealed that only Type A and C, which refers to the city/district climate action plan or low carbon development plan, presents a comprehensive approach to achieving low carbon development.

To implement the approach at neighbourhood scale, a plan that can lower carbon emissions as the core concept is required. This paper presents the urban design concepts across five CCAP sectors that can be incorporated for low-carbon development. The sectors are (i) Urban Planning, Green Cover and Biodiversity, (ii) Energy and Green Buildings, (iii) Mobility and Air Quality, (iv) Water Management and (v) Waste Management. Existing urban design concepts that can contribute to reducing carbon emissions were identified from global case studies. Supporting design strategies to implement the concepts are also mentioned. These can serve as effective tools across the given sectors mentioned in the Climate Change Action Plan (CCAP) to reduce greenhouse gas (GHG) emissions at a neighbourhood scale.

Urban planning, green cover, and biodiversity

A neighbourhood in an Indian setting could be a ward or a sector, as it is the smallest administrated unit [26]. Every neighbourhood is unique, with its own microclimate, topography, and natural resources. Therefore, urban design concepts that focus on sustainability, walkability, and proximity, such as the 15-minute neighbourhood concept, are appropriate for promoting low-carbon development [27].

Beginning with a two- dimensional designed layout, special zones for low emission can be the nodes of transition for future expansion of net zero buildings. For three-dimensional extrusion, solar envelope limits can be used to decide the maximum and minimum height of buildings depending on the street orientation and location [28]. Green cover consisting of roof gardens and green canopy on streets of neighbourhood for carbon sequestration helps in balancing out the carbon emission [29]. Setting a carbon target ward/sector-wise, allocating a carbon budget based on emission sector-wise, and nature-based solutions for controlling carbon sources and carbon sinks can help in measuring the performance of each neighbourhood.

Energy and building

Buildings and construction sectors emit around 40% of total GHG emissions on a global scale. Currently, buildings are responsible for around one-fifth of all CO_2 emissions and for roughly one-third of the nation's overall energy consumption. It is anticipated that the construction industry will increase CO_2 emissions by seven folds by 2050, as compared to 2005, if mandatory energy efficiency improvements and regulatory codes are not implemented [30]. To figure out the most carbon-emissive buildings in the neighbourhood, ' Vulnerability Mapping' needs to be undertaken [31]. This can reveal the highest carbon-emitting buildings based on their age. Such buildings can be prioritized for retrofitting or replacement. For newer buildings, superblocks would be the way forward compared to individual units in dense neighbourhoods. A superblock is a rectangular urban area bounded by arterials and main streets [32]. In the case of Barcelona, each superblock consists of 3×3 blocks (approx. 400m x 400m). Outer streets are separating them from each other. The internal street network of a superblock can take different forms. Superblocks can incorporate mixed use and rely on renewable energy

sources to increase efficiency and help decarbonize cities. These blocks are designed with the aim of incorporating a higher percentage of green spaces, reducing road networks, and promoting human and social biodiversity to ensure social cohesion whilst ensuring efficient material flow of water and energy. The Superblock project in Barcelona is a prime example of how sustainable urban planning can help reduce energy consumption [33].

Mobility and air

In a 15-minute neighbourhood layout, reducing vehicle usage and promoting walkability or cycling are key factors in reducing carbon emissions and improving air quality. Streets allocated for vehicular traffic take up more space compared to walkable streets. By freeing up public space from motorized vehicles, these areas can be repurposed as green spaces, which further aids in carbon sequestration and mitigates the urban heat island effect [29]. The concept of Green Transit-Oriented Development (TOD) prioritizes pedestrian, cycling, and transit infrastructure, mixed land uses, and sustainable building practices to achieve liveable streets, reduced emissions, minimal waste, and energy self-sufficiency. It fosters vibrant street life and closer destinations. When considering street morphology, factors such as street connectivity, width, and length are important. Studies on street centrality indicate that a 50% increase in the number of junctions per kilometre of street reduces vehicle kilometres traveled (VKT) by 15% [27]. Higher connectivity enhances permeability, making the urban fabric more vibrant and safer. Research conducted on British cities reveals a super-linear correlation between the total length of streets and CO_2 emissions, showing that longer streets tend to have higher CO_2 emissions. Narrow streets, which receive less solar exposure, tend to be cooler [28]. Street width can be managed through landscaping and street furniture rather than solely relying on building edge. Cooler streets enhance walkability. Streets also serve as ventilation corridors, facilitating air movement and the dispersal of urban heat islands.

Water Management

India's freshwater ecosystems, including lakes, reservoirs, and wetlands, contribute 4% of global GHG emissions, mainly from municipal wastewater pollution and agricultural surface runoff [34]. Water-sensitive urban design is to integrate stormwater as well as wastewater into the existing urban fabric for efficient use of all the potential water resources. It consists of a sustainable urban drainage system and decentralized wastewater management for Pollution abatement in waterbodies (source). Espino et al. conducted a comprehensive lifecycle analysis to evaluate and compare the economic, environmental, and social performance of two drainage systems: sustainable urban drainage systems (SuDS) and traditional drainage systems. The case study of the Rancho Bellavista housing development in Querétaro, Mexico, revealed that SuDS outperformed traditional drainage systems in terms of environmental and social factors. Notably, SuDS demonstrated significant advantages in reducing carbon emissions and promoting sustainability [35].

Waste Management

In developing nations, over 50% of collected municipal solid waste is not properly managed, leading to open burning or landfill disposal. This contributes to 5% of total GHG emissions [36]. In Indian cities, the average per capita waste generation is 670 grams per day, with landfills being the most common method of waste disposal. Landfill waste emits methane, which has a global warming potential 21 times that of CO_2, implying that every tonne of waste saved from landfill saves 21 equivalent tonnes of CO_2 emitted (CO_2 e). A major challenge faced in Indian neighbourhoods is the lack of a sorted waste collection system from the source [37]. The conventional techniques of door-to-door collection, truck collection, etc, have lower environmental impact in fossil fuel-based scenarios. However, in a life cycle analysis study conducted by Chafer et al. on an Automated Waste Collection System (AWCS) in Barcelona, comparing different waste collection methods and energy sources, the pneumatic waste collection system showed superior performance [38], [39]. It can be inferred that AWCS is the most efficient in terms of convenience and GHG emission, considering the source of energy is renewable energy for a neighbourhood. Further, the collected waste can be a resource through circular urban metabolism (CUM). In a CUM framework, even pollution and waste products can be reintegrated into the circular system as secondary raw materials. Table 3 showcases various urban design concepts and their implementation approaches, highlighting a few cities that have already adopted these measures [40], [41],[42].

Table 3: Low carbon urban design concepts, principles, and strategies

Sr. No.	Sector and Urban Design concept	Low carbon design principles	Low carbon design strategies	Case study
1	Urban Planning, Green Cover and Bio diversity 15-minute neighbourhood	Grid pattern	For efficient land use, it supports active transportation, facilitates energy-efficient infrastructure, and integrates green networks for urban cooling.	Barcelona
		Solar envelope	Calculation for minimum and maximum height of buildings for integrating passive design features.	Vancouver
		Open spaces (Green Infrastructure)	Infrastructure consisting of parks, green roofs, and Urban Agriculture helps in carbon sequestration and storing	Singapore
		Zoning	Low emission zones can create pollution free spots within neighbourhood	London, Berlin
		Tree Canopy	For pollution capture, temperature reduction, carbon sequestration, and storage	Bristol
2	Energy and Buildings Superblock	Adaptive reuse	Vulnerable buildings with architectural and historical value can undergo retrofitting to incorporate energy-efficient measures, allowing them to be repurposed for new uses that align with sustainability goals.	New York
		Mixed built use	Stable energy profile as the peak hours of residences is during morning and evening and commercial during the day.	Sydney
		Material selection	Incorporating low-emitting, low-carbon materials like recycled or renewable materials, energy-efficient insulation, and sustainable wood products can greatly reduce building carbon emissions.	Stuggart
		Net zero building with solar access	Ensure solar access to all buildings, facilitating the optimal utilization of solar energy.	Vancouver
3	Mobility and Air Transit Oriented Development	Street length	Main streets are linear, and arterial streets are shorter in length, lowering vehicular carbon emissions.	Barcelona
		Street width	Reallocation of road space for landscaping makes walking paths narrow & cooler.	Oslo
		Centrality	The maximum centrality of a road ensures improved permeability and shorter travel distances, enhancing accessibility and connectivity within the urban environment.	Barcelona
		Walkability and cycle paths	Walking and cycling are emission-free modes of transportation that provide well-connected paths, contributing to compact and sustainable economic development.	Copenhagen
		Ventilation corridors	It creates pathways for cool air to sweep in and reduce the higher urban temperatures.	Stuggart
4	Water Management Water Sensitive Design	Water bodies	Designed to be natural carbon sinks	Zhejiang
		Sustainable drainage system	Use indigenous vegetation, rainwater harvesting, bioretention basins and swales, and permeable surfaces for water management.	Helsinki
		Blue Infrastructure	Restoration of coastal habitats, mangroves, and seagrasses contributes to carbon sequestration in marine and coastal ecosystems.	Tokyo
5	Waste Management Circular urban Metabolism	R principle	Recycling centre as a physical infrastructure	Amsterdam,
		Disassembly and adaptability in Design	Design for disassembly and adaptability criteria of buildings through Carbon reduction or salvaging requirements for demolishing	Vancouver, Portland,
		Solid waste Network	Pneumatic waste conveyance system	Barcelona

While the paper presents principles spanning five sectors, certain limitations require consideration. This optimal solution may not align with the nuanced Indian context. Instead, a potential improvement lies in adapting selected concepts from the case study to be explored while preserving the essence of India's urban landscape.

Discussion

This study explores the current status of climate action plans of various cities in India. The paper investigates and reveals that all 128 cities have some type of climate action plan in some capacity. However, in 52 cities (40.63%) the plans are environmental plans required for improved liveability, such as clean air plans or heat action plans. The study also finds that the comprehensive climate action plan is present in 10 cities (7.81%).

It is also important to mention that the study considers only those cities that have documentation for such plans. Another notable fact is that most states have some level of State Action Plan. However, such action plans are rarely translated to city action plans, which are then to be translated into a local area plan. Hence, this study focuses on identifying cities with such action plans that can be translated into a local action plan. Additionally, in almost all States, some level of budget is allocated, and action plans have been developed. However, there is no comprehensive outlook with cities and neighbourhoods as the basic building blocks.

The paper also finds that climate action plans can be used as a reliable source for local area planning; however, one notable gap identified is the absence of carbon emission targets in the climate action plans. The carbon emission targets will help allocate carbon budgets for each sector.

As mentioned in Lifestyle for Environment (LIFE) by the Government of India, low-carbon development is a choice that India has adopted. The United Nations Environment Programme (UNEP) Emissions Gap Report 2020 has dedicated its last chapter to low-carbon lifestyles [3], [43]. Hence, a sector-wise approach from top to bottom does not suffice, but an individual's decision on lifestyle choices plays a huge role in adapting to climate change.

Every neighbourhood in India is unique, with its own history, characteristics, context, and microclimate. Therefore, a sector-based approach may miss out on many of the neighbourhood's potentials and natural resources that can be well utilized if explored. The above-given examples from each sector, as mentioned in Table 3, could be adopted based on the Indian context in such a way that it uses local resources and contributes to economic growth. A low carbon economy, therefore, would bring a major alteration in the structure of economic flow and can provide resilience to any kind of disaster by displacing the geopolitics [44]. Considering India's net zero goal for 2070, a two-way approach can bring a rapid and steady transition in switching from a high consumption pattern of energy to a self-providing situation, as mentioned in Atmanirbhar Bharath.

The conventional approach of zoning-based codes, which includes use-based and rule-based regulations that resulted in incongruent margins and street fronts, unmatched spikes in built forms, inefficient use of urban land, and loss of the neighbourhood's unique character. The shift to performance-based codes (PBCs) in urban design signifies a departure from traditional codes. PBCs prioritize achieving specific performance outcomes like energy efficiency and carbon reduction over dictating land uses and physical forms. This approach enables flexibility in implementing innovative design solutions aligned with sustainability and walkability, integrating green infrastructure.

Cities around the world are embracing performance-based codes (PBCs) in urban design. For instance, Portland mandates net-zero energy buildings, San Francisco requires LEED Gold standards, and Austin encourages mixed-use neighbourhoods. It can empower cities to address climate change and resource depletion through low-emission zones and nature-based solutions. PBCs foster sustainable communities by promoting mixed-use development and compact urban forms, reducing reliance on private vehicles, and improving air quality. Green infrastructure integration is facilitated by PBCs, leveraging urban forests, green roofs, and permeable surfaces to manage stormwater, enhance biodiversity, and improve city resilience. Collaboration among stakeholders, including planners, architects, policymakers, and communities, is crucial for successful PBC implementation. Digital tools like Building Information Modelling (BIM) and digital twin technologies further support PBC integration by assessing, monitoring, and optimizing urban designs. In summary, PBCs revolutionize urban design by prioritizing performance outcomes, leading to sustainable and resilient cities.

Conclusion

In conclusion, this paper investigates climate change-related reports aligned with respective state action plans to assess their potential integration into Local Area Plans for achieving low-carbon development. The findings reveal that, out of the 128 cities examined, only 7.81 % have comprehensive climate action plans. It is clear that cities must urgently develop such plans to combat climate change effectively. The analysis of sectoral approaches mentioned in climate action plans uncovers a promising avenue for neighbourhood development, highlighting the significant opportunity for urban design techniques and strategies to contribute to climate action goals. The urban design concepts presented in this paper can serve as a foundation for cities to establish a framework for formulating low-carbon emissions plans. Thus, it is essential for cities to explore these concepts and adopt various existing design standards and techniques to achieve their overarching goal of reducing carbon emissions.

Further scope involves delineating the implementation strategies for the recommendations put forth in the paper. Clarifying which recommendations necessitate policy-level interventions, which can be integrated into Development Control Regulations, and which could benefit from incentive-based approaches would enhance the feasibility of the

proposed urban design strategies. Additionally, an area of exploration could involve assessing the effectiveness of these strategies post-implementation, considering how their impact on promoting low-carbon development can be measured and evaluated. This would contribute to a more comprehensive understanding of the practical implications and outcomes of the suggested urban design interventions.

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