


Special Issue

निर्माण सारिका

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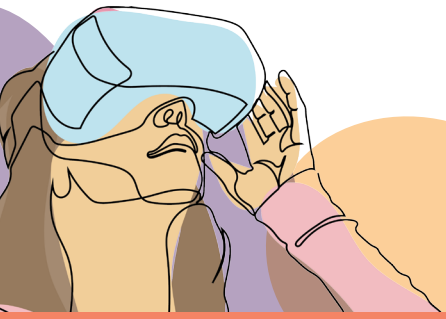
6 October 2025
World Habitat Day
Urban crisis response

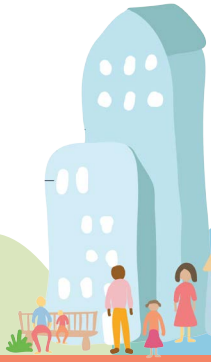
World Habitat Day

6th October, 2025

Urban Crisis Response

निर्माण सामग्री एवं प्रौद्योगिकी संवर्द्धन परिषद्
आवासन और शहरी कार्य मंत्रालय, भारत सरकार
BUILDING MATERIALS & TECHNOLOGY PROMOTION COUNCIL
Ministry of Housing & Urban Affairs, Government of India





"Creating Enabling Environment for Affordable Housing for All"

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From the Desk of Executive Director

World Habitat Day is celebrated globally on the first Monday of October each year and is recognized by the United Nations to reflect on the state of towns and cities, and on the basic right of all to adequate shelter. This year, on 6th October 2025, the Global Observance of World Habitat Day will be on the theme **Urban Crisis Response** addressing multiple crises affecting urban areas, including climate and conflicts that are contributing to inequality, and promote existing tools and approaches to effective crisis response.

India has recently seen spurt of extreme events due to climate change e.g. cloud bursts, heat waves, thunderstorms, flooding, landslides, water scarcity, fire hazards, collapse of buildings, failure of drainage system, air pollution & many more. What is most glaring is that these events are more recurrent in urban areas & become common in last decade or so. Will the pattern be same in years to follow or get aggravated, needs to be monitored? Nevertheless, have we learnt our lessons from these repeated events? The answer would be no, despite of best efforts by agencies. The reason being, we are reactive society & take measures after the event. Reactive means *Respond*, *Restore*, *Rehabilitate*. These 3Rs are detrimental for urban crisis response & need to be changed to 3Ps i.e. *Prevent*, *Plan* & *Prepare*. Globally, successful disaster management basic is to take a paradigm shift from Reactive to Proactive approach. Replace Rs to Ps for safe & resilient society. Thanks to concerted efforts by Govt. of India through NDMA, Disaster management act, policy & plan and Sendai framework for risk reduction; there are perceptible changes from relief-centric measures to pre-disaster preventive measures. However, the urban areas are grappling with climate change which exacerbates disasters & combating it, is absolutely vital for assuring our survival & the wellbeing of posterity. It is high time for urban managers to accommodate urban crisis in planning so as to make cities safe, resilient & sustainable in line with SDGs.

It gives me immense pride to pen down my last message for BMTPC's special newsletter 'निर्माण सारिका' on World Habitat Day's theme. I took reins of BMTPC in 2008 & it is my 18th message on the trot since then on every year's theme. I am due to superannuate this year & hope the legacy continues. The contributors of the articles being published in this special newsletter deserve special mention for timely & pertinent submissions. The support of Shri C N Jha, Shri Pankaj Gupta & Shri Dalip Kumar of BMTPC for bringing out the publication is duly acknowledged.

When written in Chinese, the word 'crisis' is composed of two characters. One represents danger and the other represents opportunity
- John F. Kennedy

(Dr. Shailesh Kr. Agrawal)

Building Resilience Towards Urban Crisis Response

Dr. Shailesh Kr. Agrawal *

Preamble

India on the path of unprecedented economic & infrastructural growth coupled with rapid urbanization (~820 million people will live in cities by 2050), our cities which are growing exponentially (as per census 2001, number of urban centre were 5161 which grew to 7935 by 2011 census) face increasing number of complex crises — from natural disasters & pandemics to climate related disruptions and extreme events. These crises are not only becoming more frequent, but also more interconnected and difficult to manage. As the global urban population rises which is projected to reach 68% by 2050, according to the UN; the ability of cities to respond quickly and effectively to emergencies has become a defining challenge of our time.

Urban crisis response is more than just providing emergency services in the aftermath of a disaster. It encompasses a broad range of planning, communication, coordination, and recovery efforts that span urban local bodies, public & private sectors, NGOs and communities. The following sections attempt to explore the core elements of urban crisis response, key challenges cities face, and emerging strategies to build urban resilience

Urban Crisis Response : Definition

Urban crisis response refers to the strategies, systems, and operations that cities deploy to prepare for, respond to, and recover from emergencies that disrupt urban life. These include in Indian context:

- **Natural disasters** (earthquakes, landslides, floods, cyclones)
- **Public health crises** (pandemics, water contamination)
- **Technological failures** (power grid collapse, cyberattacks)
- **Economic shocks** (supply chain disruptions, inflation)
- **Climate Related disruptions** (heat wave, air pollution)

Effective response requires coordination across multiple dimensions including multiple agencies : **infrastructure**, **governance**, **communication**, and **community engagement**.

Urban Crisis Response : Key Challenges

A. High Population Density

Urban centres pack millions into dense neighbourhoods, making evacuation, containment, and resource distribution more difficult during crises.

B. Inequity and Vulnerability

Low-income populations, migrants, and marginalized groups often live in informal housing with limited access to services. These communities are disproportionately affected during crises and may lack the resources or information needed to respond effectively.

C. Aging Infrastructure

Many cities operate on outdated infrastructure — water systems, roads, bridges which can't handle modern-day crises. This increases vulnerability to cascading failures.

D. Coordination Complexity

Urban governance is often fragmented among multiple agencies and jurisdictions, leading to delays and confusion during emergencies.

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E. Misinformation and Communication Gaps

In the age of social media, misinformation can spread faster than official alerts. Reaching the public with accurate, timely information remains a major hurdle.

Urban Crisis Resilience : Emerging Strategies

A. Data-Driven Decision Making

Globally, cities are leveraging big data and AI to predict risks, monitor incidents in real time, and make informed decisions. It is time for India to switch to these cutting-age tools rather than depending on age-old traditional SOPs. Predictive analytics can help identify areas most at risk during a heatwave, flood, or outbreak.

B. Integrated Emergency Operations Centres (EOCs)

Modern EOCs centralize coordination, allowing multiple agencies — fire, police, health, transportation — to share information and deploy resources more effectively. India under Smart Cities Mission have successfully established Integrated Command Control Centres (ICCCs) which were effectively used during COVID -19. It is time to extend the same involving all concerned agencies for urban crisis.

C. Community-Based Preparedness

Cities are investing in grassroots preparedness efforts, training local residents in emergency response, first aid, and communication protocols. When institutional systems are overwhelmed, community response can save lives.

D. Urban Design for Resilience

From floodable parks in Copenhagen to heat-resistant infrastructure in Phoenix, cities are rethinking their physical landscapes to absorb shocks and adapt to new realities.

E. Public-Private Partnerships

Tech firms, logistics providers, and other private entities often have key resources and capabilities. Collaborating with them during crises, as seen during the COVID-19 enables faster and broader response.

Urban Crisis Response : Case Studies to Emulate

Tokyo: Earthquake Readiness

With its history of earthquakes, Tokyo has invested heavily in earthquake-resistant infrastructure and public drills. The city uses sophisticated early warning systems and conducts mass drills involving millions.

New York: Climate Adaptation

After Hurricane Sandy in 2012, New York City (NYC) launched "OneNYC," a comprehensive resilience strategy. It includes sea walls, resilient power grids, and climate adaptation zones, aiming to future-proof the city against climate-related disasters.

Cape Town: Day Zero Response

Faced with an unprecedented drought, Cape Town in 2018 implemented aggressive water-saving measures, public education campaigns, and supply diversification, averting "Day Zero" — the date when water taps were predicted to run dry.

Toward a Resilient Urban Future : Closure

Urban crisis response is no longer a niche area for urban managers. It is a cornerstone of sustainable city planning and governance. As crises grow more complex, cities must move beyond reactive models towards proactive, integrated approaches that prioritize equity, data, and adaptability.

Urban resilience isn't built overnight — it requires investment, political will, and collaboration across sectors and communities. But as recent events have shown, the cost of inaction is far greater.

In the 21st century, a city's strength will not be measured solely by its economic output or skyline — but by its capacity to withstand, respond to, and recover from crisis.

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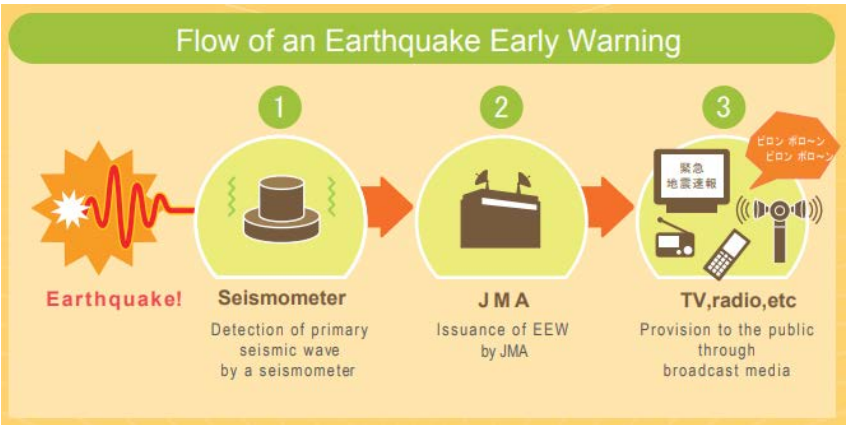

Flowchart of Tokyo Earthquake Early Warning System
Source: https://www.jma.go.jp/jma/en/Activities/eew.html

Sustainable And Healthy Housing - A Powerful Lever for a Resilient Future



Dr Sunita Purushottam [1] *Hitesh Vaidya [2]* *Ms Maaz Dixit [3]*

Cities are where futures are being made, and increasingly where futures are at stake. Two major factors contribute to this: rapid urbanization and climate vulnerability.

Over the coming decades, the world will urbanize at an unprecedented pace. According to the UN, 68% of the world population will live in urban areas by 2050, from the current 55%. And 90% of this increase is expected to occur in Asia and Africa.[1] In India, 30% of the population lives in urban areas, which is likely to increase to 40% by 2030, according to a McKinsey Global Institute (MGI report. That means adding millions of people to the already strained urban infrastructure.

This acceleration comes alongside growing climate risks. India is among the most climate-vulnerable countries. In 2024, 93% of days in the first nine months saw significant climate events like heatwaves, cyclones, floods, and landslides. The losses are devastating - 3,238 lives lost, 3.2 million hectares (mha) of crops affected, 235,862 houses and buildings destroyed, and approximately 9,457 livestock killed.[2] The climate chaos in 2025 continues. We are still reeling from the early summer, the hottest February, the early onset of the monsoon, and the incessant pounding that urban areas and major cities, such as Mumbai and New Delhi, have endured from the flood-like situations.

But it's not all doom and gloom. India recently surpassed Japan as the fourth-largest economy, and is projected to become the third-largest economy by 2030. India is also the fastest-growing major economy in the world.[3] The country has a large youth population, a demographic dividend that many developed economies are missing. To maintain momentum and ensure a sustainable future, we must make our urban infrastructure, particularly housing, sustainable, inclusive, and climate-resilient. Why does housing matter?

Housing is a powerful lever for sustainable development

When housing programs focus only on unit counts, they miss the systems where value is created. Housing sits at the crossroads of health systems, energy, labour markets, local economy and urban infrastructure. Three multiplier pathways are critical.

- **Public health** - The quality of the built environment significantly influences people's well-being. Factors such as lack of space, extreme temperatures, poor ventilation and lighting, absence of social spaces, and exposure to pollutants lead to discomfort, irritability, anxiety, depression, and ailments such as respiratory and cardiovascular diseases.[4] Sustainable and healthy housing prevents disease (through ventilation, safe water and sanitation, reduced

1 https://www.un.org/en/desa/68-world-population-projected-live-urban-areas-2050-says-un

2 Centre for Science and Environment

3 https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154660

4 Lall, A.B., Sethi, G. (2025). Design guidelines for healthy and climate-resilient affordable Housing in India. Global Buildings Performance Network (GBPN)

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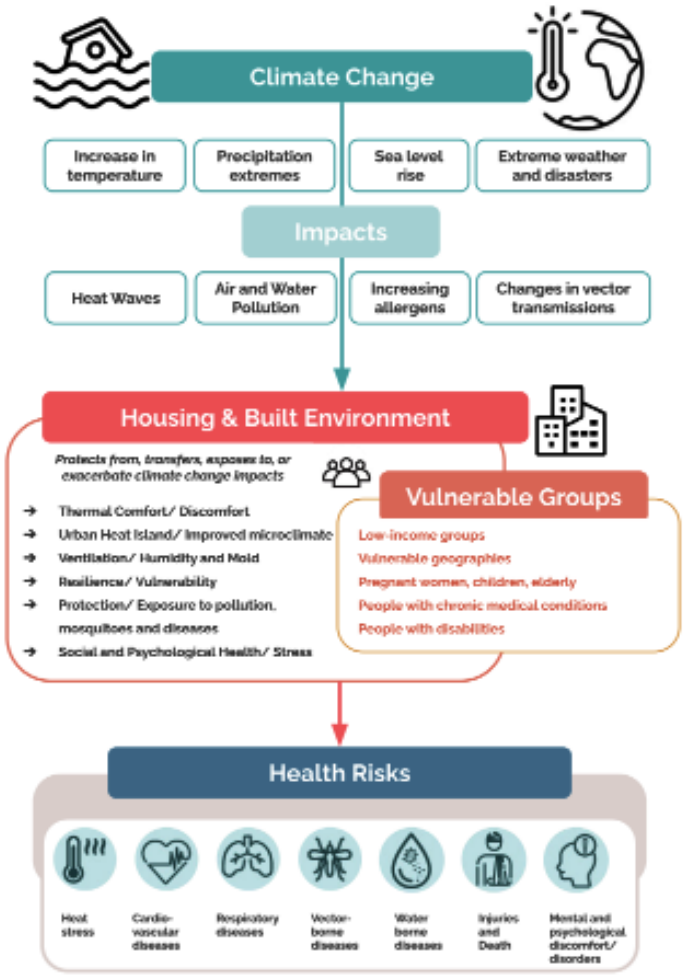


Housing and the built environment play a significant role as an interface that transfers or protects residents from the risks and impacts of accelerating climate change, which have various health outcomes for those with different vulnerabilities. (Source: Design Guidelines for Healthy and Climate-resilient Affordable Housing in India, 2025. © GBPN 2025)

crowding), reduces domestic violence and supports mental health.

- **Climate and energy** - The cumulative emissions (direct and embodied) from buildings are expected to reach 21% of India's total emissions in a BAU scenario. Cooling demand will drive the energy demand in India. Decarbonisation and energy-efficiency interventions have the potential to reduce emissions by up to 43%.[5]
- **Economic inclusion** - According to an OECD report,[6] Poor-quality housing has a detrimental impact on education and health, resulting in long-term financial consequences. The type and location of housing are important drivers of people's access to economic, social and cultural opportunities. Secure, affordable housing reduces household vulnerability, unlocks labour mobility and creates local economic demand (materials and services), especially when combined with local skills development and supply-chain support.

What does the right to adequate housing mean?

The recent Supreme Court of India ruling on the right to protection against climate change is a landmark ruling. The court ruled in M.K.Ranjitsinh & Ors v. Union of India & Ors. (2024), that "right to be free from the adverse effects of climate change" is integral to the fundamental rights enshrined under Articles 21 and 14 of the Indian Constitution. According to Article 25 of the International Charter of Human Rights, everyone has the right to adequate housing, which must provide thermal comfort, refuge, and health benefits through sustainable design and technology.[7] The right to adequate housing was recognised as part of the right to an acceptable standard of living.

The UNHRC identifies housing as a right, and not as a commodity. And yet, access to adequate housing is far from universal. Housing must be treated as a human right and form part of government policies and programmes.

Challenges in delivering sustainable housing for urban India

India's urban transformation is a developmental success. At the same time, it is a governance challenge. Rapid growth, constrained land, rising real estate prices, infrastructure deficit, persistent informality, economic inequality, and climate change combine to leave millions without durable, secure, and healthy housing.

- **Service delivery gaps** - Formal market supply often fails

5 Center for Study of Science, Technology and Policy, 2024

6 An Agenda for Housing Policy Reform

7 UN OHCR, Accessed Online 2023

to reach low-income households. Public programs have increased delivery but face implementation hurdles, especially for the most marginalised. The growing demand for energy and water, waste management, transport, and housing units will outstrip supply if current trends continue.

- **Exposure to climate risk and disasters** - Many low-income settlements neglect climate-resilience and are located on floodplains, riverbanks and degraded land. Recurrent displacement from storms and floods amplifies vulnerability and undermines long-term investment in home improvements, as well as economic development support.
- **Health-sensitive design gaps** - Affordable housing frequently neglects indoor environmental quality (ventilation, daylight, moisture control), leading to poor respiratory and mental-health outcomes. The public health literature is clear that housing quality is a major social determinant of health.
- **Affordability constraints -** Access to finance, subsidies or lower-cost, sustainable materials is uneven. The lower-income classes still make up a large share of urban dwellers; many have limited ability to pay for higher-quality, climate-resilient and sustainable housing.
- **Fragmented governance and capacity at the local level** - Delivery requires coherent action across urban planning, health, energy, water and housing ministries and agencies, as well as national, state and local governments. Improved multi-level coordination and stronger subnational capacity are essential to deliver sustainable housing to all.

Role of local governments and a bottom-up approach

In India, urban development is a state subject. The Twelfth Schedule of the Indian Constitution (74th Constitutional Amendment Act of 1992) lists 18 functional items under the purview of municipalities, including urban planning, land use and building regulations, water supply, public health and sanitation, roads and bridges, urban poverty alleviation, and slum improvement.[8] This makes the local governments the delivery nodes for urban development outcomes, including housing. Decentralised decision-making can be a strength, as local authorities are closest to the context and can prioritise incremental upgrading. However, decentralisation only works when backed by clear mandates, adequate funding, reliable data, and technical support. In practice, a bottom-up approach entails empowering municipalities with targeted fiscal transfers and capacity-building initiatives, equipping them with user-friendly data tools to identify risks and needs, providing digital tools for effective implementation and monitoring, and fostering collaborative processes that enable communities to co-design solutions that are culturally and spatially relevant.

Healthy Buildings - at the unit and the urban scale

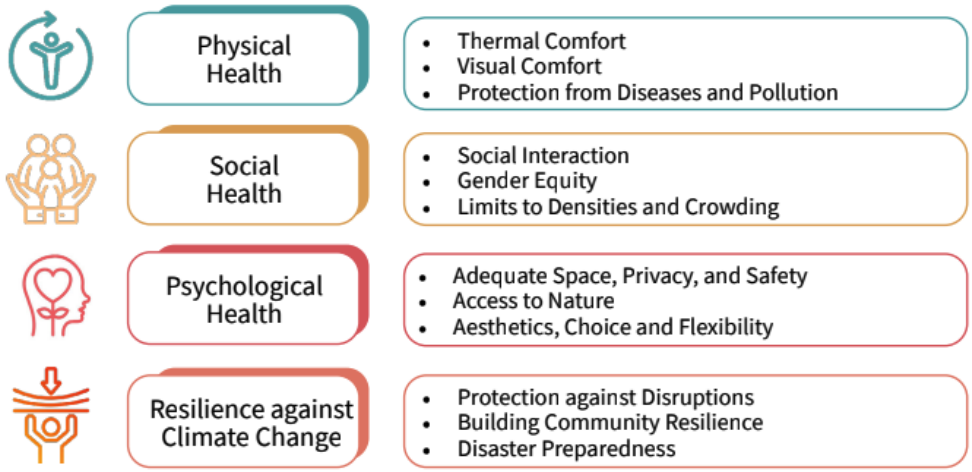
What is a healthy building? The Global Buildings Performance Network (GBPN), along with local expert partners, Ashok B Lall Architects (ABLA), in their project on Healthy Affordable Homes, identified four determinants that make a home or building healthy: Physical Health, Social Health, Psychological Health, and Resilience against Climate Change.[9] The recommendations have been finalized into the 'Design guidelines for healthy and climate-resilient affordable Housing in India', and form part of the draft circulation of the revised National Building Code. The Design Guidelines provide planning and design standards that prioritise the health and well-being of residents for implementation by architects, builders, and Urban Local Bodies (ULBs) developing affordable housing. The Guidelines take an occupant-first approach, with extensive research and recommendations from affordable housing occupants informing the design.

But health and resilience at the housing unit level are not sustainable if the neighbourhood and the city are not climate-resilient and do not incorporate health parameters. Urban planning must include green and blue infrastructure, integrate climate resilience, connect housing planning to transport, jobs and services, and create carbon assessment tools and implementation support. An integrated, evidence-driven urban development planning sits at the intersection of climate, health, sustainable development, and national commitments to the Sustainable Development Goals (SDGs).

The GBPN project, in its next stage, will collaborate with local

8 https://mohua.gov.in/upload/uploadfiles/files/2688HUA-ENGLISH-19-4-2023.pdf

9 Lall, A.B., Sethi, G. (2025). Design guidelines for healthy and climate-resilient affordable Housing in India. Global Buildings Performance Network (GBPN).



The determinants of health in low-income housing in the context of climate change. Applicable to the individual home, the building, the residential community, and the neighbourhood. (Source: Design Guidelines for Healthy and Climate-resilient Affordable Housing in India, 2025. © GBPN 2025)

bodies to develop Healthy Urban Planning Guidelines that integrate health, low-carbon development, and climate adaptation options into urban development planning. The Guidelines aim to counter challenges such as weak infrastructure, pollution, limited parks and green spaces, and unplanned urban development, while supporting the design of sustainable, resilient, and livable cities.

Looking forward - Recommendations for sustainable urban development in India.

There is intent and willingness on the government's part to incorporate sustainability and climate-resilience into its urban development agenda. The recent amendments to the Energy Conservation and Sustainable Building Code (ECSBC) and the upcoming revised National Building Code are steps in the right direction. Adoption at the state level and implementation at the urban local level will be key to ensuring that sustainability, health, and future resilience are at the forefront of urban spatial and economic development. Key priorities should include -

- **Adopting health and resilience metrics into housing and urban planning**

  Make indoor environmental quality, thermal performance and flood risk part of program eligibility and monitoring (for new builds and retrofits). Green and blue infrastructure must be included at the planning stage for urban development. Use standard, simple indicators so local governments can act quickly.

- **Scaling low-cost passive design in affordable housing**

  Mandatory orientation guidelines, shading, roof and wall insulation, materials which reduce heat gain, ventilation specifications, wall-to-window ratio and restricted use of glass should be part of the design code for public-subsidised housing. These measures minimise cooling demand, improve comfort and limit lifecycle costs. Passive measures are among the highest value interventions. [10]

- **Strengthening municipal finance and technical capacity**

  Decentralisation works when revenue tools, technical assistance and clear mandates are aligned. Fiscal transfers should reward measurable outcomes, such as the number of resilient units upgraded and the percentage of units meeting health performance standards.

- **Mobilising blended finance and targeted subsidies for green affordable housing.**

  Public grants, concessionary loans, green bonds and performance contracting can combine to make higher-quality materials and retrofits affordable for the poorest households.

- **Embedding community participation and local expert collaboration**

  Programs that co-design incremental improvement pathways with communities and local experts are more likely to be adopted, maintained and scaled. Participatory planning improves equity, respects cul-

10 https://www.mdpi.com/2071-1050/15/18/13544

tural preferences and reduces implementation friction.

- **Coordinating action across ministries**

  Creating frameworks for collaboration across ministries, development and delivery agencies, national, state, and local governments can help mainstream resilient, healthy, and sustainable housing standards across government schemes.

Translating ECSBC's 'what' into the city-level 'how'

The Energy Conservation and Sustainable Building Code (ECSBC) and the forthcoming revision of the National Building Code (NBC) represent significant national-level commitments to sustainability, energy efficiency, and resilience in the built environment. However, for these codes to be effective, cities and municipalities — the ultimate implementing agencies — need practical frameworks, tools, and benchmarks that translate national provisions into local action.

This is where the GBPN's Design Guidelines for Healthy and Climate-Resilient Affordable Housing in India provide critical value. They give the municipalities a toolkit to implement national codes in a way that is locally relevant, health-focused, and equity-driven, while creating a policy feedback loop that sustains dialogue across scales:

1. **Decoding technical standards into actionable design parameters**
   - The ECSBC sets ambitious energy performance and sustainability targets; however, municipalities often struggle to translate these into practical planning and design decisions.
   - GBPN guidelines simplify these targets into unit-level design elements (orientation, shading, ventilation, insulation, passive cooling, daylighting, indoor air quality) and neighbourhood-scale provisions (green/blue infrastructure, climate resilience, connectivity to jobs and services).
   - This helps Urban Local Bodies (ULBs), architects, and builders operationalise ECSBC provisions without compromising the intent.
2. **Bridging national codes with local priorities**
   - While the NBC and ECSBC are designed as national frameworks, implementation in India must reflect local climate, cultural practices, and economic realities.
   - GBPN's guidelines provide context-sensitive pathways that cities can adopt incrementally — such as low-cost passive design, local materials, and participatory planning with communities.
3. **Embedding health and resilience as part of compliance**
   - ECSBC focuses on energy and sustainability, while GBPN's guidelines extend this to include health and well-being metrics (ventilation, daylight, moisture control, thermal comfort).
   - This strengthens the policy dialogue by aligning housing interventions not just with climate goals, but also with public health, equity, and social inclusion outcomes.
4. **Supporting capacity-building at the municipal level**
   - The guidelines serve as a training and decision-support tool for municipalities, enabling them to develop bylaws, tender documents, and monitoring frameworks that are aligned with ECSBC.
   - By linking clear design standards to measurable outcomes (e.g., reduced cooling demand, flood risk mitigation, improved indoor air quality), they make it easier for ULBs to demonstrate compliance and attract financing.
5. **Advancing and sustaining policy dialogue**
   - The GBPN process encourages co-design with local experts and communities, ensuring that lessons learned from the ground level inform national policy refinement.
   - Create a feedback loop where ECSBC/NBC provisions are tested, adapted, and scaled in cities, while evidence from implementation informs future revisions of codes and housing policies.
   - Keep the conversation active between multiple stakeholders — ministries, state governments, ULBs, financiers, architects, and civil society — ensuring that sustainability and re-

silience remain at the centre of India's housing and urban agenda.

Conclusion - Dignity, Resilience and Sustainable Growth

Urbanization is one of India's defining forces: it can be the engine of growth, inclusion, and innovation. Or it can widen inequalities, deepen climate risk, and erode health. Housing sits at the intersection. If we build better, healthier, more resilient homes in better places, with stronger systems, we do more than provide shelter; we safeguard lives, livelihoods, dignity, and opportunities for inclusive and sustainable growth. The choices we make now matter. India must get its urban system right — planning, governance, finance, services, and housing. The challenge is political, administrative and technical: to align ministries, finance and communities around a shared, measurable vision. If we can overcome these challenges, the prize is a country of safer, fairer, and more resilient cities, realising the promise of urban India.

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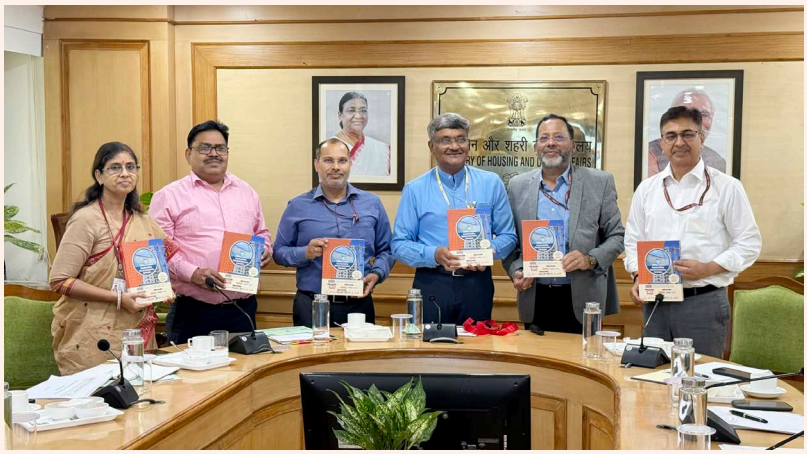
Release of Publications by Secretary, HUA, Govt. of India

Shri Srinivas R. Katikithala, Secretary, Ministry of Housing & Urban Affairs (MoHUA) released the following books during the 67th meeting of the Executive Committee of BMTPC held on 7th August, 2025 at New Delhi:

Book titled "Innovative Building Materials and Construction Technologies"

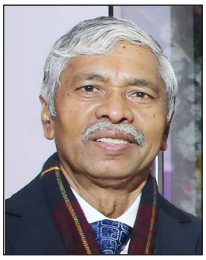


The Council organised a National Conference cum Expo on Innovative Building Materials & Construction Technologies (IBMCT-2025) on March 19-20, 2025 at New Delhi so as to bring all stakeholders at one platform to share their knowledge and experience. The papers presented during the IBMCT are brought out as Proceedings titled "Innovative Building Materials and Construction Technologies". The publication cover wide range of topics ranging from cutting-edge materials, construction technologies to efficient, sustainable, net-zero processes and contains 26 papers written by well-known experts and institutions covering different areas of building materials and construction practices.

Book titled "Alternate & Innovative Construction Systems for Housing" – 2nd Edition

The 2nd edition of the book titled "Alternate & Innovative Construction Systems for Housing" has been brought out by the Council as lot of additional innovative materials, processes & technologies have been added such as 3D printing, digitalisation, IoT, robotics & automation, cloud computing, etc. This book serve as resource material to the NAVARITIH – Certificate Course on Innovative Construction Technologies being implemented by BMTPC, MoHUA and SPA New Delhi under PMAY-U.

Drainage Crisis in Urban India



Dr. K. M. Soni *

Drainage has become a major challenge in almost every urban area. During rains, life gets halted in most of the urban areas as the underpasses and roads become pools for some time due to poor drainage system. Over it, due to climate change the areas which were considered low rainfall areas are experiencing heavy rains and high rainfall areas are getting further higher discharge leading to submergence of bridge decks and even failure of the bridges. Coastal areas are experiencing high tides, due to which rain water gets stagnated due to closure of gates as water does not flow into the sea from gravity. Therefore, the drainage problem is turning into a national problem.

Climate change is considered the cause of such abnormal rains and floods. Even if such conditions are due to climate change, engineers have the responsibility of resolving the drainage issue and save the property, resources, livestock, and human lives.

Climate change and weather change

Climate change is referred to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions. The climate change is primarily said to be due to the burning of fossil fuels like coal, oil and gas generating greenhouse gas emissions (GHGs) that act like a blanket wrapped around the Earth trapping the sun's heat and raising temperatures. Main GHGs responsible for the climate change are carbon dioxide and methane, coming from using petrol/diesel (gasoline) for driving vehicles or burning coal for heating buildings, generating electric power in thermal power plants or deforestation. Methane comes from agriculture, oil and gas operations. Therefore, energy, industry, transport, buildings, agriculture and land use are said to be cause of GHGs. However, everyone understands that more and more such services are required due to population growth and increasing luxury lifestyle of people. Since population growth, ever growing luxury lifestyle and resulting urbanization cannot be stopped, governments are finding out the ways and means to switch over to the energy sources of net zero carbon emission. As such, *climate change* has become a global issue and the nations have already started taking action to control it, some targeting it by 2050 and others by 2070. However, at local level weather change has entered silently and posing a great challenge to urban planners and engineers due to severe and frequent flooding in urban areas, landslides, collapse of houses, bridges and communication lines, and damage in roads, highways, resulting into wastage of resources, livestock and human lives. For example, Rajasthan and Kerala are experiencing heavy rains, Himachal Pradesh and Uttarakhand are experiencing frequent cloud bursts and landslides, Bihar and UP are experiencing heavy rains and bridge collapses, and Delhi and Rajasthan heavy water stagnation.

To contain GHGs, governments globally are switching over from coal based thermal generation to the renewable sources considering it clean, accessible, affordable, sustainable, and reliable but the study of the effect of unsustainable use or over exploitation of solar energy and wind is also not undertaken. It is also not known whether overexploitation of solar and wind energy will

* Former ADG, Central Public Works Department (CPWD), New Delhi

alter regional weather conditions, further complicating local weather conditions, resulting into change of rainfall pattern altogether.

Urban drainage and urban planning

Urban planners plan civil infrastructure, economic infrastructure, energy infrastructure, and service infrastructure but never gave serious thought on urban drainage which was left to local engineers of the municipal bodies. Municipal engineers also gave priority to the creation of new infrastructure, thereafter to the improvement of services which require less efforts like improvement of road riding surface, footpaths, and parks. New infrastructure development, particularly dense multi-storeyed construction further deteriorated the conditions of existing drainage in brownfield development. Inadequate maintenance and desilting of drainage system also reduce the capacity of the drainage system.

Due to inadequacy of the drainage system, drainage system has collapsed. When water gets stagnated, rain water is discharged into existing sewer lines at few places as such sewerage system is also collapsing in the urban areas. Inadequate drainage system resulting into water stagnation affects road surface, footpaths, water supply, waste management services, communication services, building foundations, basements, flyovers, retaining structures, culverts, bridges etc. become prone to the failure, particularly of substandard quality and less maintained.

Urban planning of slum area is further difficult. Slums develop near major drains or on the banks of major drains being government land. As initially slums do not have sewerage system, raw sewerage is dropped into the storm water drains. Such growth of slums on the banks of major drains pose difficulty in silt clearance. Unauthorised development also poses problem of poor drainage as they develop without proper roads, sewerage, and drainage system. Later, when the development is regularised, sewerage system is provided but creating proper drainage becomes difficult due to constraint of space and connectivity to existing major drains.

Many a times, FAR/FSI is increased in existing planned areas without consideration of capacity of drains and discharge capacity of the urban drainage system leading to overloading of services leading to its failure.

Climate and weather change has further made drainage issue complicated. Whatever are the reasons, engineers and urban planners have to improve poor drainage infrastructure as they are responsible of the same.

Causes of failure of the drainage system

Some of the reasons of the failure of drainage system are given in the following;

I. Design issues
II. Coordination issues
III. Administrative and political issues
IV. Maintenance issues
V. Financial issues
VI. Quality issue
VII. Climatic issues

• Design issues

Drainage is not given adequate importance hence the design of the drainage system itself may be inadequate and might not have been designed. Various executing agencies involved in construction of individual buildings, campuses, roads, flyovers either do not design the drainage system or connect to the existing system, sometimes with the approval of local bodies and sometimes even without approval. Local bodies also many a times accord approval without going into details of its capacity. In most of the urban areas, design experts of the drainage system are not available and expert consultants are also not engaged.

Another design issue is of impervious surfaces. Architects, engineers, builders and individual building owners provide impervious surfaces due to which surface drainage exceeds. Lakes, ponds, wells and baolies are sometimes filled up or reduced in area leading to increase in surface drainage.

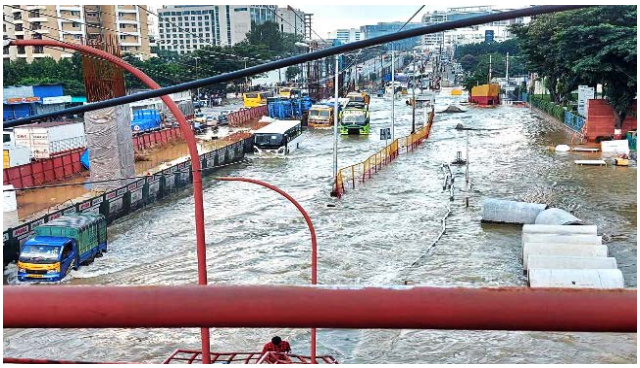
• Coordination issues

Co-ordination lacks within various government and private agencies as such every agency takes up construction and maintenance work at their own, resulting into large construction and demolition (C&D) waste, leaving excavated materials, stacked construction materials, and other municipal waste on the roads flowing into the drains during rains.

Agencies working in urban areas link their drainage system of the campuses with existing inadequate drainage system. Agencies responsible of construction of roads and flyovers leave the drains without taking it to the streams or rivers, rather connect to the existing inadequate drainage system.







• Administrative and Political issues

Drainage being a local body issue, is largely influenced by administrative and political issue. Government and private agencies approach them for according the approval of connecting the drainage system in existing municipal system even if the same is unable to carry additional discharge and may be forced to accord the approval else the created assets may remain unused for long time. Sometimes, approval is accorded based on financial considerations as the local bodies may not have required budget for their ongoing expenditure, thus without technical considerations.

Removal of unauthorized construction and encroachment mostly become political issue as the politicians have social responsibility and may not allow to remove the encroachers even if the encroachment is blocking the drainage system. Increase in FAR/FSI is also an administrative and political issue and the engineers have hardly any say in the same.

• Maintenance issue

Maintenance is not given required weightage and least compared to the original construction. Most of the engineers are interested in executing construction. Similarly, it becomes difficult to get technically sound and financially capable agencies for maintenance works. This may lead to substandard maintenance. Incidents of poor and inadequate desilting of drains, lakes and ponds are reported frequently.

Though large number of rain water harvesting (RWH) works are undertaken but least maintained as silting of ground water recharging system constructed under RWH is common.

• Financial issue

Most of the local bodies do not have adequate funds for construction of new major drains, augmentation of existing drainage system and sometimes even for maintenance and repair of existing drainage system. If the funds are available, priority is not given to allocate the funds to improve the drainage system.

• Quality issue

This issue is related to all agencies involved in the construction and maintenance of various structures and services. Substandard construction and maintenance such as of roads, footpaths, drains, lead to erosion of the substandard materials used in the construction which ultimately flow to the drainage system and either block the drains, or leads to siltation limiting the carrying capacity and even overflow. The agencies carrying out construction, spread materials like soil, sand, aggregates and C&W waste on the roads or site which flow into the drains during rains or swept into the drains.

• Climate change issue

As already discussed, climate change also increases discharge into the entire drainage system and also in the streams, rivers and sea. During floods, drainage from the drains of urban areas does not flow into the streams and rivers as such water gets stagnated till the flood level recedes.

Suggested measures

Flooding in most of the cities during rains indicates that the drainage has become inadequate. Therefore, each state government should consider it the issue of state level and draw up an integrated plan to resolve it by taking up planning, construction and maintenance in an integrated way at least for five years. Further, till the time, drainage system is not augmented, the following measures are suggested;

i. No infrastructure project should be sanctioned without drainage system.

ii. Without augmentation of drainage system, change in FSI/FAR should not be allowed.

iii. Old streams, lakes, wells and baolies should be rejuvenated and reconstructed.

iv. Planning policy should include less impervious surfaces and strictly followed. During maintenance period, this should be monitored and no change allowed.

v. Desilting should be taken up in all drains, lakes, ponds and baolies to make them fully functional.

vi. New lakes, and ponds should be created in open areas, parks and gardens.

vii. All rain water harvesting and ground water recharging structures should be inspected and certified for their functioning.

viii. No protection should be given to the encroachers on drainage system and encroachment on drainage system should be banned through enacting required laws.

ix. There should be a third-party certification for the mainte-

nance work carried out related to drainage system.

x. DPRs should be prepared for improving the drainage system of urban areas to take up the works at state or national level.

xi. Rain water drainage and sewerage system should not be allowed to be mixed.

xii. Execution of the work related to drainage should be taken up by state or national level agencies, making them accountable for the work done.

Effects of water stagnation

Water stagnation and flowing water affects the structures mainly foundation, embankments, road and bridge surfaces, drains, and dampness in the buildings. Therefore, the engineers have to design new structures considering stagnated conditions and take strengthening measures in existing structures, some of these are listed in the following;

i. The bearing capacity of soil gets reduced due to water hence the bearing capacity of soil should be derived considering water level at footing or ground level in all the places.

ii. The high flood level (HFL) should be based on past data and estimated HFL in future due to floods.

iii. Drainage system should be designed considering flooding in all urban areas based on futuristic demand.

iv. Infrastructure should be designed considering flooding in the urban areas.

v. Specifications of Damp Proof Course (DPC) should be revised considering water stagnation.

vi. All flyovers and roads should be mandatorily designed and executed with the drainage system.

vii. All basements should be designed for water filled up conditions.

viii. Urban flooding should be considered on a mission mode at national level.

Conclusions

The following conclusions are made;

i. Urban drainage problem needs to be considered at national level.

ii. Bearing capacity and settlement analysis should be made considering water flooding so that the structures do not fail during flooding.

iii. All bridges should be designed considering interpreted HFL with the data of climate change and past records.

iv. Urban drainage system and structures should be designed considering futuristic rains.

v. Encroachment of the drainage system should be removed.

vi. Lakes, ponds and baolies should be made part of drainage system.

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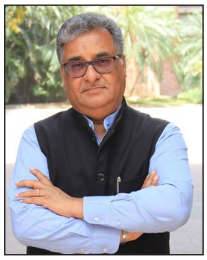
Training Program on "New Construction Materials and Technologies" at Indian Institute of Coal Management, Ranchi

The Council received request from IICM Ranchi for handholding their engineers and architects on new construction materials and technologies. Accordingly, a two days Training Program on "New Construction Materials and Technologies" was organized by BMTPC during February 6-7, 2025 at Indian Institute of Coal Management, Ranchi, for the executives belonging to the civil engineering discipline of Coal India Limited and its subsidiary companies.

During the program, advancements in the field of environment-friendly, energy-efficient & innovative building materials and construction technologies were covered. Along with the key presentation from BMTPC, the Technology providers of 3D Volumetric concrete construction and 3D Concrete Printing made presentations. A field visit of Light House Project at Ranchi was also organised for Coal India executives and technical & sustainability details of the LHP were explained to them.

Urban Flooding:
From Crisis to Resilience through Blue Green Infrastructure



Sanjay Seth [1] *Anushree Harde* [2] *Sonal Singh* [3]

As world becomes warmer, the urban areas are increasingly facing the brunt of climate change with warming levels twice as fast as the global average. The extreme weather events such as droughts and floods are becoming frequent, long lasting and severe over the years. India's population is expected to reach 1.69 billion by 2054 as per World Population Prospects 2024 report which result in increased built up area thereby reducing the capacity of the cities to absorb storm water resulting in increased run-off. Often, the existing storm water drainage network is unable to handle the increased water flow resulting in inundation within the cities often referred to as "urban floods". Urban flooding across India has shifted in the last two decades from episodic catastrophes into a recurring, city-wide crisis. Most of India's 10 largest cities have experienced multiple flood events in the past five years (2020-2025), not only during peak monsoon but even after intense short-duration rainfall. Built-up cover in the 0-20 km zones of many of these cities has risen by about 47% on average between 2000-2015, with some cities seeing over 100% increase in impervious surfaces in that zone significantly reducing natural recharge areas.

From Chennai's 2023 monsoon deluge to the 2024-25 floods across Vijayawada, Punjab, and Uttarakhand, the frequency and intensity of urban flooding are clearly rising. In Vijayawada, for instance, more than 29 cm of rain fell in a single day, causing the Krishna River and Budameru rivulet to overflow, claiming over 35 lives and affecting nearly 270,000 people. Delhi faced a series of intense rainfall events in July 2025 that submerged arterial roads, paralyzed traffic, and even forced the closure of Connaught Place, showing how even moderate rainfall can cripple a megacity with inadequate drainage. A study undertaken by IIT Roorkee (2023) for Yamuna flooding found that unplanned expansion into floodplains and loss of permeable surfaces were key drivers of heightened risk, while Punjab's August 2025 floods submerged 2.5 lakh acres of farmland and impacted over 3.5 million people, underscoring the importance of river-basin governance and early warning systems. These recent events highlight the pressing need for climate-sensitive urban planning and stormwater management that moves beyond ad-hoc relief measures, towards a systemic resilience approach.

What used to be localized inundation handled by emergency relief and temporary drainage now regularly disrupts transport, health services, and economic activity in many metropolitan cities. Current losses due to pluvial flooding are about USD 4 billion annually, projected to reach USD 5 billion by 2030 and USD 14-30 billion by 2070 without urban resilience measures. This pattern is a wake-up call that urban flooding is no longer merely a natural hazard rather a systemic urban crisis that reflects gaps in planning, infrastructure and governance. It also calls for a paradigm shift in urban planning from merely

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responding to disasters to proactively fostering resilience.

Historically, Indian cities have addressed flooding mainly through emergency response pumps, sandbags, makeshift diversion, and ad-hoc repairs of clogged drains. These stop-gap measures, however, are increasingly inadequate. Over the five decades, as incidents of very heavy rainfall increase significantly, India has experienced a 63% rise in "extremely heavy rainfall events" (≥ 204 mm/day). Although the total yearly rainfall has not increased significantly, drainage systems designed for earlier eras are being overwhelmed. Compounding this, governance shortcomings such as unplanned urban expansion into flood plains, encroachment of water bodies and natural drains, and poor solid waste management which leads to drain blockages are now regular contributors to urban flooding damage. Data from National Disaster Management Authority (NDMA) indicates that urban catchments magnify flood peaks by 1.8 to 8 times and flood volumes by up to 6 times, compared to rural catchments, resulting in rapid onset of flooding and frequent service disruptions.

Climate change is altering India's monsoon dynamics, not simply by increasing total rainfall but by making it more erratic, intense and concentrated. Research shows that sub-daily, high-intensity rainfall events are increasing in frequency across many locations raising the risk of flash floods. At the same time, urbanization continues apace: cities are growing rapidly outward, replacing vegetated land and wetlands with impervious surfaces like concrete and asphalt, reducing infiltration and increasing surface runoff. Many Indian cities have seen large shrinkage of water bodies and open green areas, exacerbating the flood risk. Furthermore, the urban heat island effect intensifies convective rainfall in some contexts, while poor maintenance and outdated drainage infrastructure often cannot keep up with these intensified pressures. The compound nature of these risks means that what were once exceptional flood events are now becoming routine, especially when storms hit in short bursts or during already saturated soil conditions.

I. Blue-green infrastructure for Flood-Resilient Cities

While urban floods become a recurring phenomenon in our cities, it also presents an important opportunity to focus on climate resilient and inclusive infrastructure. As 50 percent of India's urban infrastructure required till 2050 is yet to be built the focus on grey infrastructure like reservoirs, water pumps, sewage treatment plants as means to mitigate flooding needs to move beyond traditional concrete based approach to more sustainable practices in line with 21st century climate risks. The inclusion of blue-green infrastructure (BGI) not as optional intervention but as central to city building and revitalization of degraded urban ecosystems. Traditional approaches

The blue-green infrastructure while providing mitigative strategies against reducing the impact of climate risk also improves quality of life. While there is no standard definition of Blue-Green Infrastructure. The green infrastructure is categorized as parks, forests, green roofs and other vegetative elements while blue infrastructure includes lakes, wetlands, and other water bodies. The blue and green elements are integrated together, unlike initiatives that focus on single intervention such as green infrastructure, water-sensitive planning, stormwater management and others which often overlook the interconnected nature of the complimentary systems. Within the realm of urban planning BGI is referred to as a "holistic urban planning approach that is aimed at creating interconnected networks of green and blue spaces within urban areas". For instance, Delhi Development Authority (DDA) while formalising the Master Plan 2041 formulated the green-blue policy for the city. The concept of "Sponge Cities" pioneered in Wuhan, China effectively captures principle of BGI by using vegetation to absorb water run-offs and riparian flows. Similarly global case studies like Raincity Strategy, Canada; Grey to Green Initiative, Portland USA among others that focus on enhancing environmental services, land zoning and city development plans

Most importantly BGI not only mitigate physical risks of flooding but also provide social wellbeing and health benefits with improved access to blue-green spaces in concrete cities. At policy level while the country lacks an institutionalised BGI strategy but over the years several initiatives have addressed the different aspects of blue and green elements independently. The National Action Plan on Climate Change (NAPCC) formulated in 2008 through its 12 missions cover aspects of sustainable habitat, water and forestry among others. Along with NAPCC, two flagship initiatives i.e. Smart Cities Mission

and AMRUT focus on sustainable urban infrastructure, with scope for cities to introduce BGI. In addition to above initiatives, Indian cities like New Delhi, Bhopal, Madurai and Bengaluru have been at the forefront of adopting blue-green elements to their urban planning.

II. Institutionalizing Blue-Green Infrastructure

In order to drive adoption of BGI a multi-pronged strategy that addresses governance, financing, planning and participation is critical. It offers substantive benefits to address the demands of sustainable urban renewal and environmental protection through a well-defined strategy at different levels of government. Some of the key parameters that can be considered include

1. Blue-Green Urban Strategy: Introducing local area-based approaches with an overarching framework at national level to establish uniform definitions, statutory and regulatory provisions. This will provide an umbrella for individual states and cities to formalize their unique approaches. Furthermore, existing policies and initiatives can be expanded to include the strategy of nature-based solution while implementing projects. This ensures that existing funds can cater to implementing blue green strategies.

2. Financing Framework: The high costs of introducing or retrofitting blue-green infrastructure in dense urban areas needs innovative financing tools. Unlike grey infrastructure where the project funding is straightforward, with clear outputs. The cost benefit analysis of a BGI project requires a more nuanced approach making financing such projects difficult. Therefore, tools like bonds, international funds, financial pooling and even a national level blue-green fund can be introduced.

3. Multi-stakeholder Participatory Approach: Any policy level change requires collaboration and coordination across diverse range of public, private, academic and civil society organizations. It ensures awareness about BGI while encouraging joint ownership and management. It roots the project in local context with communities ensuring accountability. Further, the blue green elements cover diverse range of administrative units (Municipal Corporation, Development Authority, Water Department and others) and often across jurisdictions which requires close coordination to ensure effective implementation.

Blue-green infrastructure has critical role to play as Indian cities plan to integrate climate resilient strategies. While the concept has found some ground in Indian cities but its institutionalisation in India's development strategies is yet to be seen. Therefore, a comprehensive approach that aligns the national priorities Viksit Bharat by 2047 is climate resilient requires approaches like blue-green infrastructure.

The intensification of urban flooding across Indian cities underscores that the challenge is no longer a question of rare natural disasters but a recurring outcome of intersecting factors such as rapid urbanization, loss of permeable landscapes, inadequate drainage infrastructure, and changing climate patterns. The evidence from recent flood events highlights how transport systems, health services, and local economies are brought to a standstill, revealing systemic gaps in planning and governance. As Indian cities expand, the opportunity lies in reimagining urban planning to prioritize resilience over short-term relief. Blue-Green Infrastructure (BGI) offers a pathway to not only mitigate flood risks but also enhance livability by restoring ecological balance, improving public health, and future-proofing cities against climate shocks. Institutionalizing BGI through integrated policy frameworks, innovative financing mechanisms, and multi-stakeholder collaboration will be central to this transition. Moving from reactive measures to proactive, climate-sensitive planning is essential if India's cities are to remain engines of economic growth and meet the vision of a climate-resilient Viksit Bharat by 2047.

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Training Programme on Vulnerability Atlas of India

The DANICS officers (the Delhi, Andaman and Nicobar Islands, Lakshadweep, Daman and Diu and Dadra and Nagar Haveli (Civil) Services), the bureaucrats of the Union Territories of India, were imparted training on Vulnerability Atlas of India - A tool for Disaster Mitigation & Management at Delhi Technological University (DTU), New Delhi.

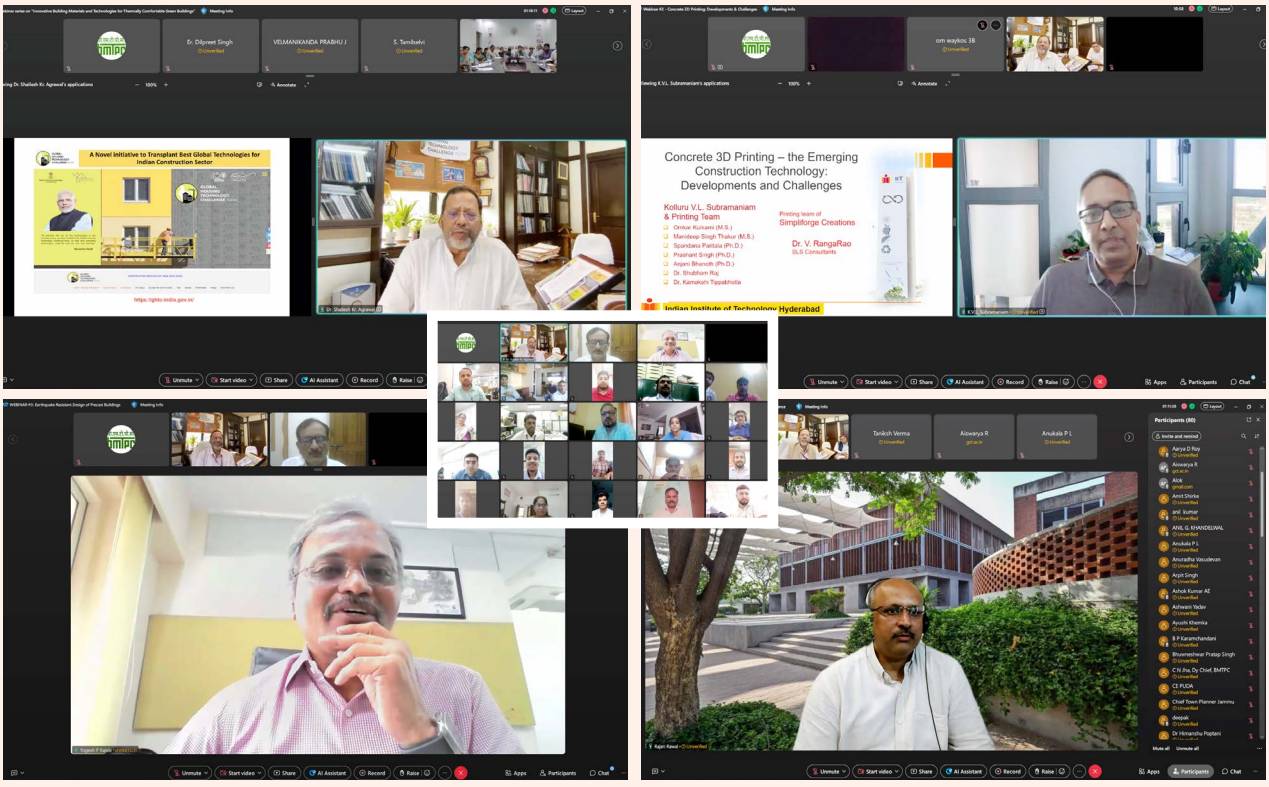
The Atlas published by BMTPC is unique document collating digitised information up to district levels of natural hazards namely earthquakes, wind/cyclones, floods, landslides, thunderstorms. Also, it contains qualitative damage risk levels for existing housing stock for each district based on walling material & roof type as per Census 2011.

BMTPC Webinar Series on "Innovative Building Materials and Technologies for Thermally Comfortable Green Buildings"

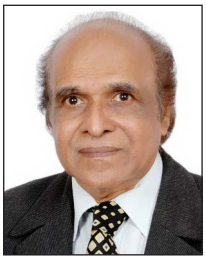
To disseminate the use of modern, green, and innovative building materials and technologies for sustainable quality housing under PMAY-U 2.0, BMTPC has launched a Webinar Series on "Innovative Building Materials and Technologies for Thermally Comfortable Green Buildings." The aim of the webinar series is to spread awareness about cutting-edge materials, sustainable solutions and emerging technologies that enhance thermal comfort and energy efficiency in modern green architecture including resilience against natural hazards.. Four webinar has been organised till now.

The series is designed to benefit State Government Officials, Architects, Engineers, Developers, Professionals, Students and other Stakeholders involved in housing policy, planning, design and execution in the housing sector including PMAY-U stakeholders & agencies.

Webinar #1	**Topic: Technology Transition through Light House Projects (LHPs) under PMAY-U** Speaker: Dr. Shailesh Kr. Agrawal, Executive Director, BMTPC Date: June 25, 2025 Participants: ~170
Webinar #2	**Topic: Concrete 3D Printing - the Emerging Construction Technology: Developments and Challenges** Speaker: Prof. K. V. L. Subramaniam, Deptt. of Civil Engg., IIT Hyderabad Date: July 23, 2025 Participants: ~160
Webinar #3	**Topic: Earthquake Resistant Design of Precast Buildings** Speaker: Shri Y. P. Kajale, Sr. Vice President, BG Shirke Construction Technology Pvt Ltd. Date: August 20, 2025 Participants: ~120
Webinar #4	**Topic: From Body to Building: The Third Skin and the Building Science** Speaker: Prof. Rajan Rawal, CEPT University & Sr.Advisor CARBSE, CEPT Research & Development Foundation Date: September 17, 2025 Participants: ~90



Strategic Pathways to Combat Delhi's Urban Crisis



A.K. Jain *

The theme of the World Habitat Day (6th October 2025) is 'Urban Crisis Response and Promoting Solutions and Localisation', with a focus on urban resilience and recovery. Delhi, the National Capital, is passing through several urban crisis viz. air pollution, climate change, river Yamuna pollution and flooding, traffic congestion, slums and shelter. The paper deals with these urban challenges and their effective responses.

Delhi, the Capital of the country has been a forerunner in urban planning and development. After the 17th Century Shahjahanabad and 20th Century New Delhi, its planning and development was carried forward by Delhi Master Plan (1962), which was followed by Master Plan for Delhi 2001, and Master Plan for Delhi 2021 (Fig. 1).

During last six decades the city has witnessed all round development of land, housing, infrastructure services, greenery, industrial and commercial centres, roads, flyovers, metro network, railways, bus terminals, conservation of heritage, recreational facilities, etc. However, the capital city continues facing the following crisis and challenges:

1. Air pollution
2. Climate change
3. River/ water pollution and flooding
4. Traffic congestion
5. Slums and informal settlements

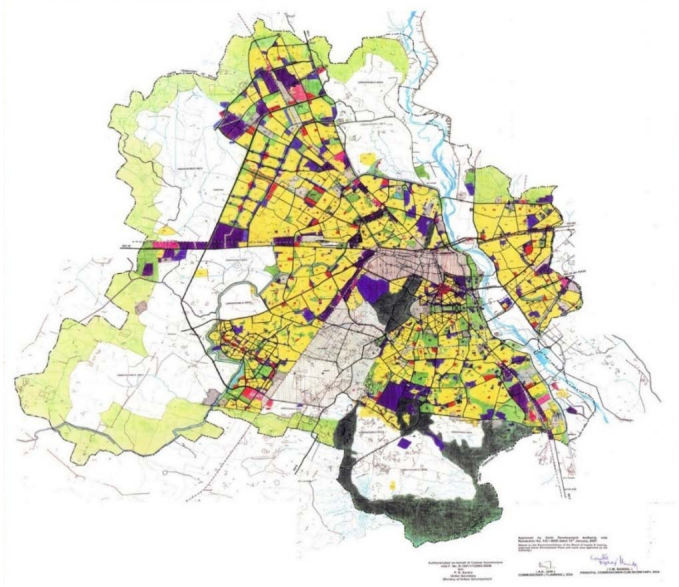


Fig. 1: Master Plan for Delhi 2021
Source: DDA

Pathways Towards Clean Air

The most dangerous thing in Delhi is not crime or traffic but the air. It is a silent killer hiding in plain sight. $PM^{2.5}$ and PM^{10} particles, dust, nitrogen dioxide (NO_2), Ozone (O_3), sulphur dioxide and carbon monoxide (CO) are linked with several diseases and deaths. Beyond health, these impact the ecosystem- water, built environment, infrastructure and economic productivity. Clean air is a human right and is key to make the city liveable. For this it is imperative to adopt various solutions, such as zero polluting industries, green transport, nature-based solutions, renewable energy, circular economy, smart buildings and services.

The strategic pathways for clean

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air involve a synergy of Technology, Citizen Engagement and Policy Matrix that addresses critical factors of air quality (industry, energy, urban mobility, environmental data, building and construction and farming). The Delhi Pollution Control Committee on 9th May 2025 invited the Indian Institute of Technology, environmentalists and others for submission of a concept note on combating air pollution in Delhi. Accordingly, the author submitted a paper on Strategic Pathways Towards Clean Air (Table 1)

It is suggested that the PRAGATI (Pro- Active Governance and Timely Implementation) Platform and Whole of Government Platform may be adopted for its seamless implementation Our children's future depends not on assigning blames and salvaging a broken status quo, but on writing new rules for clean air that the National Capital deserves. The pathway requires building a coalition which is flexible, result oriented that bypasses bureaucratic gridlocks.

Climate/Disaster Resilience and Heat Mitigation

According to the United Nations Framework on the Convention on Climate Change, the predicted impacts of climate change in India include a surface air temperature rise up to 4° Celsius by 2100, up to 30% decline in yield in rain-fed areas for some crops and an increase in incidences of extreme events, such as droughts, floods and cyclones, which are being associated with climate change. According to the IPCC (2021), the global temperature rise should be restricted to 1.5 degree Celsius. With carbon emissions at 1.2 metric tons (mt) per capita/year, India is one of the lowest in the world but has been caught in a vicious cycle of climate change (Fig. 2).

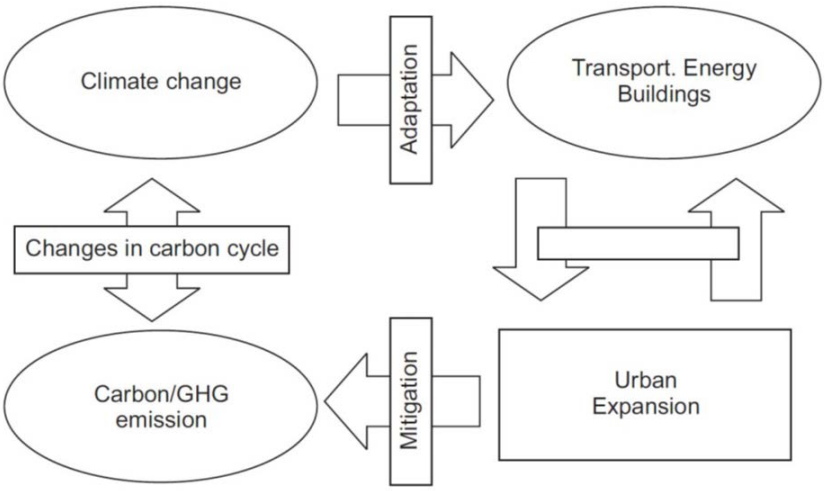


Fig. 2: Vicious Cycle of Climate Change
Source: UN Habitat (2010)

Already in the urban areas the people with cars and air conditioners emit 4.5 mt of carbon dioxide/ greenhouse gases per year, while the low-income people without car and air conditioners, emit an average of 1.1 mt of CO_2/GH gases. As per UN Climate Change Panel, a benchmark of 3.0 mt of carbon emission per capita per year should be the upper limit.

The cornerstone of making a city resilient is to adopt an integrated approach towards ecology and the conservation of the natural resources. The composite urban environment includes the environmental infrastructure – greenery, water supply, air, sewerage, solid waste management, transportation and energy. It is necessary to strike a balance between conflicting demands - citizen freedom versus safeguarding community interests, economic opportunity versus climate and disaster resilience, public services versus mandatory procedures.

According to the Intergovernmental Panel on Climate Change ((Climate Change Report, 2014, WG III), the critical aspects of sustainable spatial planning comprise:

- Density, FAR optimisation, compact and integrated development
- Land use (mix of activities, population), inclusiveness
- Connectivity, walkability and traffic density
- Accessibility for all by public transit, cycle, walking
- More resilient, healthy environment, buildings and services.

Location is most important for the livelihoods of the informal sector workers who cannot afford to lose time and money in commuting. As a principle, the distance between work and living should be below 15 minutes by public transport, cycle or walk, that is 10 km, 3 km, and 1 km respectively. In view of recent work from home trend due to corona pandemic, it may be mandatory to provide at least half of the built space for work-life integration and mixed land use. This will save the need to commute (Fig.3 & 4).

The increased indoor temperature severely affects the produc-

Table 1: Strategic Pathways Towards Clean Air: 5 year Action Plan

	Manufacturing and Industry	Energy	Urban Mobility	Environmental Data	Building Construction	Farming
Technology	• Installing continuous emissions monitoring technology (CEMS) at manufacturing locations, placing more accountability on industrial polluters • Development of low-emission commercial and industrial vehicles, processes and logistics • Optimise industrial infrastructure and promote industrial restructuring • Accelerate technological innovations • Bio-mediating legacy wastes	• Emission and fossil free technology • Trigeneration • Renewable Energy/ PM Suryaghar Yojana (Rooftop Solar Systems) • Zero Net Energy Building • Use of Gaseous Fuels • Elimination of D.G. Sets • Smart Meters • Micro Grids • Battery swapping • Energy efficiency • Decentralised solar system	• Make Delhi a 15 minute city by mixed use and public transport • Development of low-emission public transport • Greening of roads/pavement • Increase the use of electric cars/e-rickshaws • NMTs, pedestrians • Transport Demand Management • Transit Oriented Development • Delhi Electric Vehicle Interconnector/EV Infrastructure (Delhi public bus scheme) • Faster Adoption and Manufacture of Electric Vehicles (FAME) • End of Life Vehicles (Private and Public) • RFID enabled points • Audit of PUC Centres	• Installing citywide air quality monitoring networks. • Communicating air quality data through mobile Apps • Anti-smog guns and rooftop sprinkles on Multi storied buildings • Cloud seeding	• Net zero/ Green building • Cool roof • Heat Mitigation Plan • Water Spray to offset heat and dust • Passive design, Natural ventilation, • Swales, green strips, trees and Indoor plants • Green Rating • Dust Control • Air Filter	• Use of agriculture residue for power generation • Conversion of Agri-waste material into bio-char • Satellite surveillance • Gasification technology to convert bio-waste into pellets/ electricity • GIS/PVT System/ • Greenhouse Farming • PM Kusum Scheme (Solarisation) • Carbon Capture Technologies • Wind Power • Energy Storage • Biofuel stoves/ PNG, smokeless chullah
Citizen Engagement	• Applying public pressure on polluting industries • Promote citizen engagement in industrial environment management • Disclosure of air pollution data	• Renewal energy • Campaigns against Firecrackers, noise, insanitation, waste-burning, etc. • Facilitates reduced energy consumption	• Providing N-99 pollution masks and safety to traffic policemen, municipal workers, etc. • Initiating a public campaign for car pooling and ridesharing	• Vayu Apps • EIA • Early warning system • 5 Rs of Waste Management	• Green building movement • Incentives for GRIHA rating • Promote citizen participation	• Incentives and infrastructure for recycling agriculture residue
Policy	• Allow only zero waste industry, close violating industries • A cap-and-trade emissions scheme for industries • Ensuring compliance of industrial emissions and functioning of CETPs • Enforcement, Common Digital Platform • Institutional and legal review • Strengthen environment threshold and industrial layout • Clarify responsibilities of government, enterprises and civil society	• Emission Tracking Systems • Install clean energy production and supply	• Building support for tighter controls on vehicular emissions • Increased use of electric vehicles	• Actionable use of environmental data. • Implementation of Graded Response Action Plan and National Clean Air Program (NCAP)	• Facilitating the use of green rating for building's	• Schemes for management of agricultural waste and waste to energy • Blockchain Technology • Smart Digital Processes

Source: Author with inputs by the ASHA and Clean Air 91

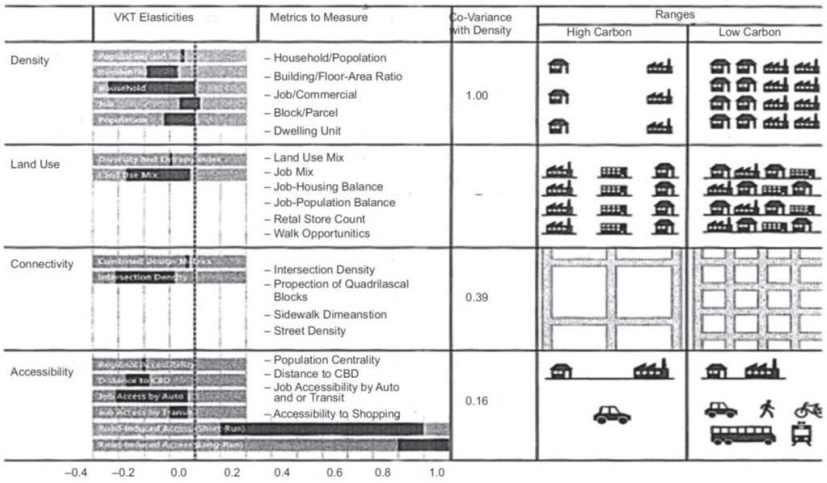


Fig. 3: Density, Land Use, Connectivity and Accessibility for Sustainable Urbanism
Source: IPCC (2014)

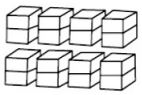
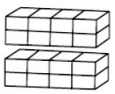
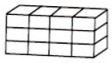
Building form	 *8 separate houses (ground floor plus basement)*	 *2 terraces of 4 house} (ground floor plus basement)*	 *block of 8 flats (2 storeys plus basement)*
Site area	100 %	70 %	34%
Envelope surface area	100%	74 %	35%
Heating energy	100 %	89 %	68 %
Construction costs	100%	87%	58 %

Fig. 4: Comparison of Surface Area, Energy Consumed and Construction Costs for Eight Housing Units in Different Configurations
Source: Presig H.R, et al. Okologische Baukampetenz in Dominique Gauzin -Muller (2002) Sustainable Architecture and Urbanism, Birk1hauser, Basel

tivity of women and home-based workers, resulting into reduced incomes. There is a need to work out heat mitigation plans for urban areas with appropriate and local cooling technologies, ventilation and cool roof.

Ahmedabad is drafting a cool roof technology policy framework with Ahmedabad Municipal Corporation, Indian institute of Public Health Gandhinagar and NRDC India. This involves low-income areas to learn about electricity consumption patterns and how building design and materials can generate less heat, e.g. tar roads could be replaced by concrete blocks. Ahmedabad's action plan has set up drinking water fountains for the public, a cool roof initiative and early warning system for vulnerable population. Solar reflective white paint over roof has been applied in existing housing and tenements, that drops inside temperature by 3 to 4^0 C. SEWA Trust has been helping the people in this task. Under the Heat Action Plan, Ahmedabad has made reflective rooftop mandatory for all municipal, commercial and government buildings. Buildings, roads and pavements made with reflective or permeable materials retain up to 20% less heat. A study found that porous bricks and concrete can lower the pavement surface temperature by 12^0C and 20^0C respectively and air temperature by 1^0C. Porous asphalt absorbs more water and is cooler. Double glazed windows and two layered walls separated by an air gap can also insulate buildings from the solar heat and reduce energy consumption.

Trees provide shade, moisture, and can reduce city temperature by up to 10^0C. Covering exterior surfaces of a buildings and other structures with vegetation is also helpful. Vienna has launched a cool street initiative and parks and streets have been redesigned to be cooler, using tree plantation and replacing asphalt with surfaces that reflect less heat. Mobile shade dispensers and stations offer drinking water and spray cooling. Paris has created a network of 100 cooling islands with parks and pools linked by walkways. Residents can locate them using smartphone app. Stuttgart (Germany) has created cool corridors, which help clean air flow throughout the city. Miami-Dade County, Florida has installed cool pavements with tree canopies to increase shade cover. Medellin in Colombia has created 36 green corridors covering 36 hectares along major roads and waterways. The corridors connect the suburbs and urban centres. The UN Environment Programme (UNEP) says that temperatures have fallen by up to 4^0C. In 2007, Ljubljana, Slovenia's Capital pedestrianised more than 10 hectare of the city centre, free of motorised vehicles and pavements were made wider with bike sharing. Free electric taxis were made available for tourists, infirm and the elderly.

A climate-sensitive design approach (CSDA) recognizes that the design of a built-up area directly influences the climatic comfort in an urban environment. The Asian Development Bank in its report

'Green Urban Planning' (2022) depicts an approach that integrates ecology, service networks, transport, built environment and heritage. (Figs. 5 and 6).

For a scientific analysis of carbon emissions and impact on climate change, a climate compass can be developed for the urban processes- ecology, resources, health and wellbeing and place making (Fig. 7). It predicts the impact of various urban projects on the environment and climate. There is a need to establish dedicated climate centres for cities. The physics of climate change must be woven into our economic fabric and not treated as a standalone sector. Climate resilience must be embedded in urban planning, economic strategies, energy security and jobs, clean power must go hand in hand with a future ready economy. Clean energy is creating jobs, anchoring the decentralised renewable energy (DRE) technologies, which reduce emissions and act as economic multipliers for resilience and an inclusive growth.

With digital chips, the cities, buildings and infrastructure services are increasingly getting digitally scripted. Information technology can enhance users experience by high-speed communication and data management, carbon-emission accounting and performance objectives. This implies integrating circular, green concepts with smart, ICT based planning, architecture and technology to optimise their sustainability and resilience (Fig. 7 to 9).

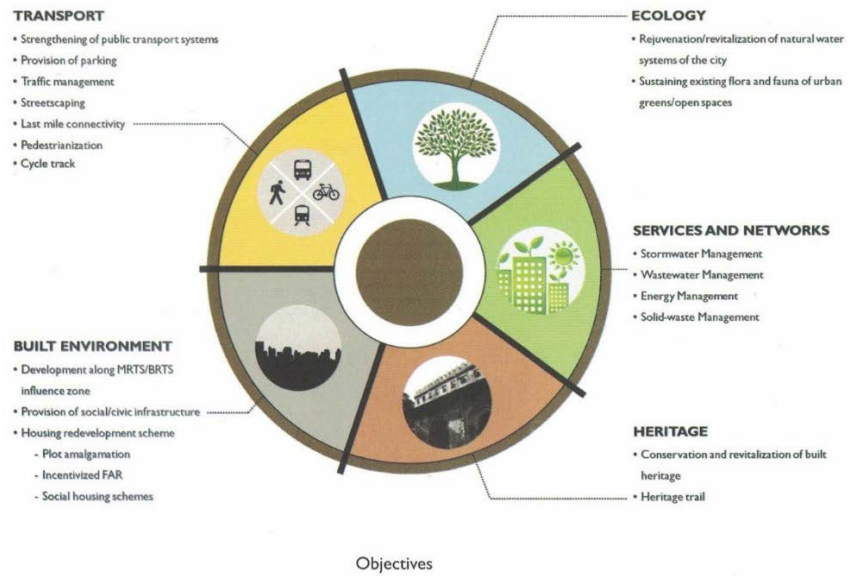


Fig. 5: The Local Area Plan of Ward Level Provides a Pragmatic Canvas to Address the Local Issues, while Integrating the Ecology, Services and Networks, Transport, Built Environment and Heritage

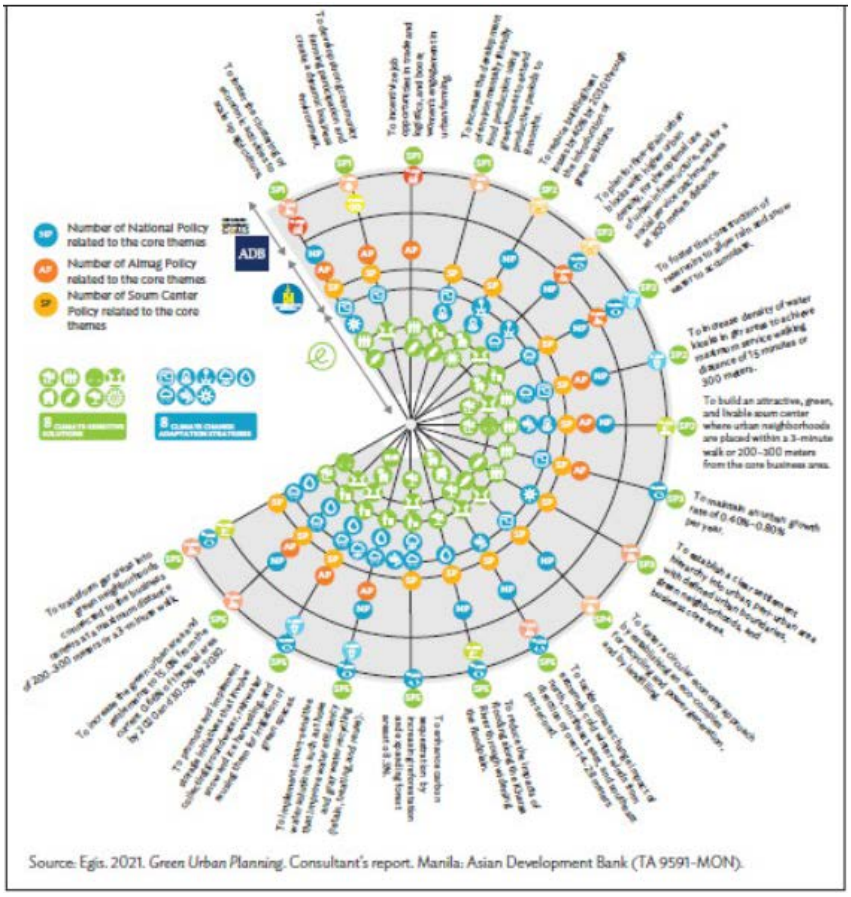


Fig. 6: Green Urban Planning - an Integrated Approach
Source: ADB/Egis, 2021 Green Urban Planning Consultant's Report, Asian Development Bank, Manila

River/ Water Pollution and Flooding

During the recent Delhi assembly elections, the polluted waters of the Yamuna became a campaign issue, and the government has initiated river-cleaning. While the immediate cleaning operations include trash skimming, weed harvesting and dredging, these will have to be long-term and overarching. The river zone in Delhi covers 9,934 hectares and the river flows in a length of 48 km. It is flanked

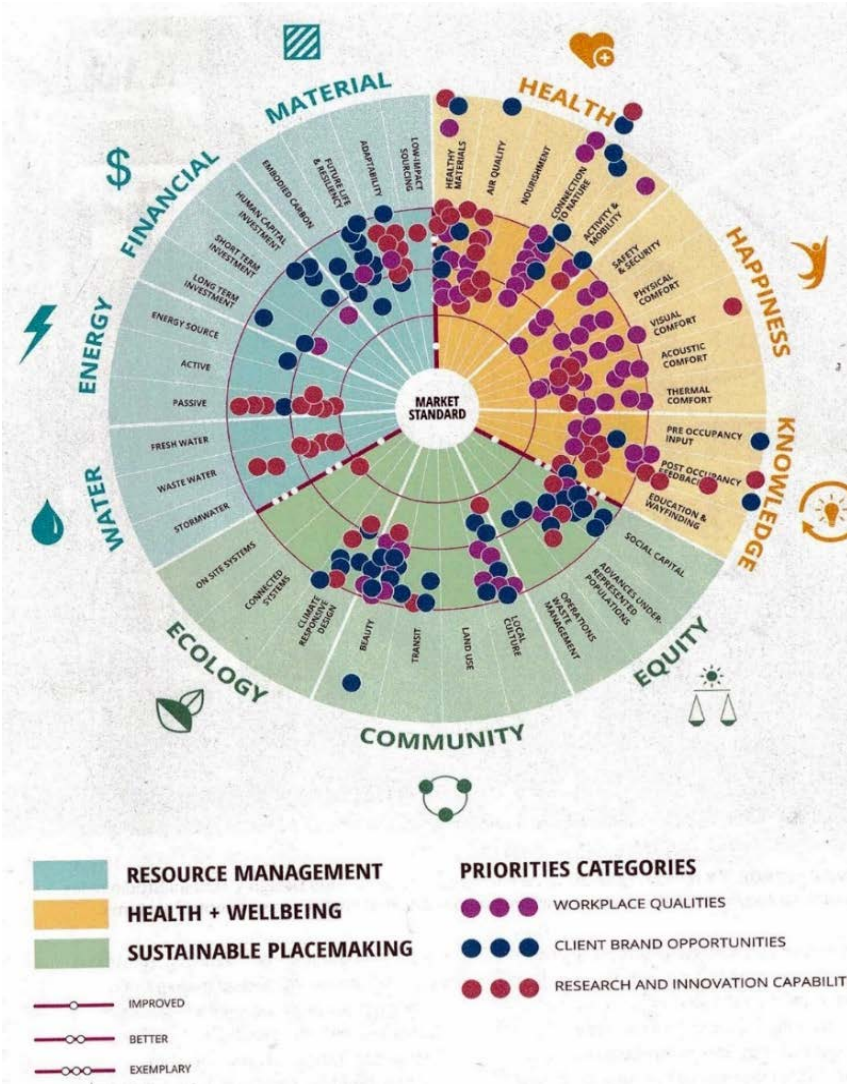


Fig. 7: Sustainable Project Compass Developed by SERA, Architects Converges Health, Happiness, Knowledge, Equity, Community, Ecology, Water, Energy, Financial and Material aspects of Design of Built Environment (Portland, Oregon)
Source: Kathrine Logan (2022) The Conversation, Architectural Record, April

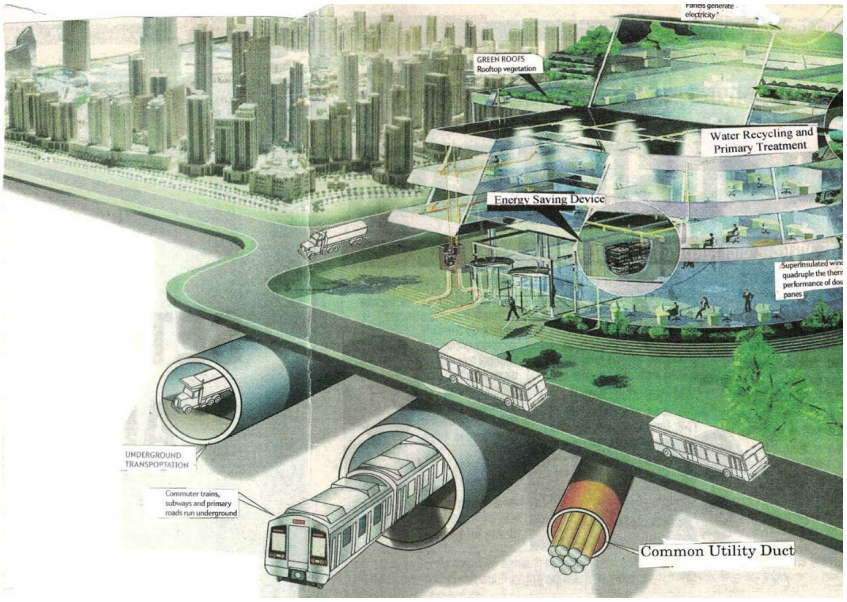


Fig. 8: New Vision for Inclusive, Intelligent, Inter-connected and Integrated Delhi
Source: Author

by the river Hindon in the east and the Sahibi (Najafgarh drain) in the west. The Yamuna is integral to the Ganga riverine system (Figs. 10 and 11). The river zone in Delhi haD been used for power stations, samadhis, housing, offices, stadia, temples, cremation ground, an IT park, and illegal sand mining. More than 161 unauthorised colonies have come up in this zone which discharge their effluents and waste into the river. These have altered the river regime and endangered its water quality.

During the last 50 years, freshwater vertebrates in the river have declined by 83%, groundwater has depleted, and there is a serious loss of biodiversity. The embankments and construction have constricted the water flow, resulting in frequent flooding. With indiscriminate urbanisation, industries, unsewered colonies, fly ash and garbage dumping, the river has become a corridor of filth, garbage, squatting and insanitation.

Besides 31 planned Industrial Areas, the Government of Delhi vide gazette notifications dated 2nd December 2005 and 30th June 2006 regularised 23 non-conforming industrial clusters in Delhi. These are without any safeguards for disposal of their effluent, that ultimately gets into the river. The microplastics in the river also contaminate and leach the river water. The level of dissolved oxygen goes up to 70 mg/litre (against acceptable level 6.1 mg /litre), faecal coliform as high as 84 million mpn/100 ml. (against acceptable limit of 1200 mpn/100ml), and ammonia level at 7.2 mg/l (against acceptable 3.0 mg/l). The studies of the various rivers in India and abroad indicates that these are integral to the ecol-

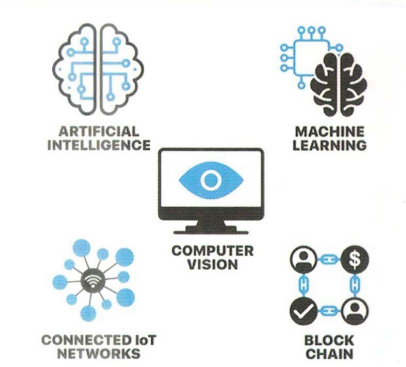


Fig. 9: New Technologies for a Sustainable and Resilient Urban Future

ogy, biodiversity, environment, geology and hydrology and should be treated as living organism.

As about 75% of river pollution is due to lack of sewerage of adjacent areas, the installation of treatment facilities (STPs and ETPs) for unsewered areas is a priority. This involves removal of non-compatible, pollution generating land uses from the river zone, provision of the sewerage of areas along the river and controlling the dumping of solid waste and effluents in the river. Interceptor sewers along the major drains, Common Effluent Treatment Plants and Sewage Treatment Plants (STPs) and building up decentralised STPs, Decentralised Wastewater Treatment System (DEWAT), bioswales and revival of water bodies. Recycling of wastewater and Zero run-off drainage with the provision of swales, retention ponds, etc. can help in optimizing the surface and groundwater.

Innovative and economical solutions like primary treatment, bioremediation, oxidation ponds, aeration, etc. can effectively to treat the pollution of the river. For treatment of pesticide traces, capping the existing sand bed with bituminous charcoal or coconut shells can be an inexpensive so-

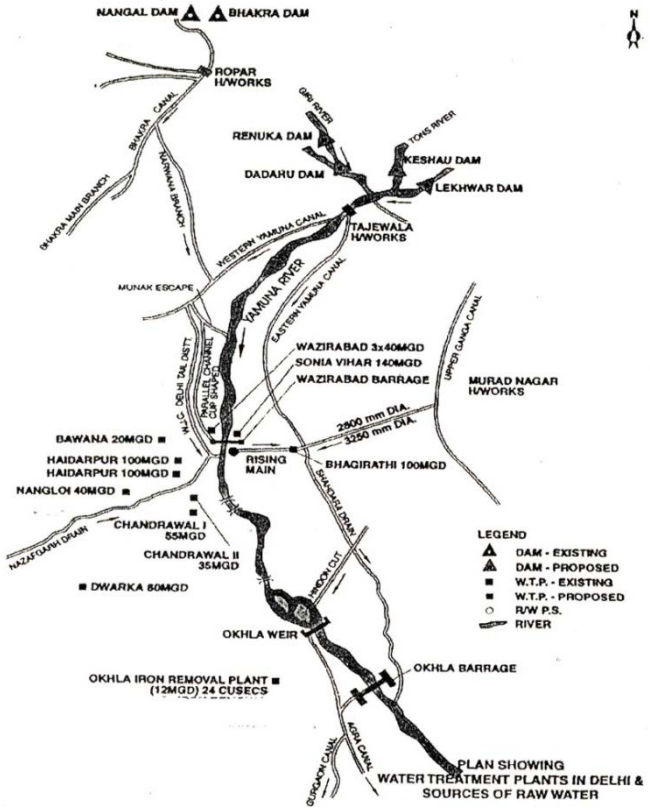


Fig. 10: River Yamuna in Delhi flows in a length of 48 km and River Zone covers 9934 Ha of area. Delhi has a 350 km long network of canals and major drains and more than 1,043 water bodies

Source: WAPCOS

Fig. 11: The origin and arrival of River Yamuna in Delhi

Source: Centre for Science and Environment, 2012

lution. Increasing flocculants by adding powered activated carbon (PAC) or bentonite clay with doses varying from 25-30 mg/l and the use of granular activated carbon can be effective. Raw water and rainwater tanks can be protected by clay beds, secured from getting washed away during the monsoons. The best way to get rid of the pesticides (non-point) and industrial toxins is through "source protection measures", such as organic biological forestry, floating wetlands, advanced bio-lace filtration, biodigesters, steel mesh, robotics bubble curtain, waste shark barriers, floating debris intercepting devises, etc.

The soft landscape, wetlands and vegetation along the riverbanks allow rainwater to be absorbed rather than running off. Natural in-stream elements, e.g. root wads provide slow-water habitat for fish and insects that regenerate native wetlands and conserve the river biodiversity. Green filters and bioswales provide eco-friendly drainage (Fig. 12). Creating balancing ponds for slow surface run off propagate and recharge the water table. Drainage, integrated with rejuvenation of lakes, canal and riverfront can prevent flooding of urban areas, damage to roads and buildings and reduce risk of water-borne diseases.

The Centre for Science and Environment under the Namani Ganga Mission published a Handbook for Planning and Designing Water Sensitive Cities for the Ganga Basin (2023). It stresses that the conservation of existing water bodies and baolis or stepwells (dug out water tanks) (Fig, 13) are essential. As the river is related with the water supply, sanitation, flooding, drainage, and transport networks, these need to be planned together by participation of the people, infrastructure agencies and other stakeholders.

As nature-based solution, Delhi Building Byelaws (2016) mandates compulsory rainwater harvesting for the buildings. However, it is more essential that the storm water from the roads and unpaved areas is also conserved that enriches the water table.

In-Situ Community Engagement is a prerequisite for the success of river conservation. This involves behaviour change for water use, pollution control and social audit. It addresses local issues by way of creating public- private-people partnership and adopt process-based community approach for circulatory and participatory water management by mapping the socio-cultural activities, festivals and natural resources.

Sustainable Urban Drainage: For many residents the testimony of urban planning is drainage that withstands flooding due to storm-water downpours. The recent burst of extreme rainfall in Delhi and the NCR (August/September 2025) submerged most of the roads and halted traffic exposing the failure of planning and abdication of duty by local government. The blame is often put on unprecedented population growth, climate change, encroachments, illegal construction, lack of implementation, enforcement and coordination, besides lack of desilting and maintenance of drainage network. As the problem of flooding continues year after year, it is necessary to

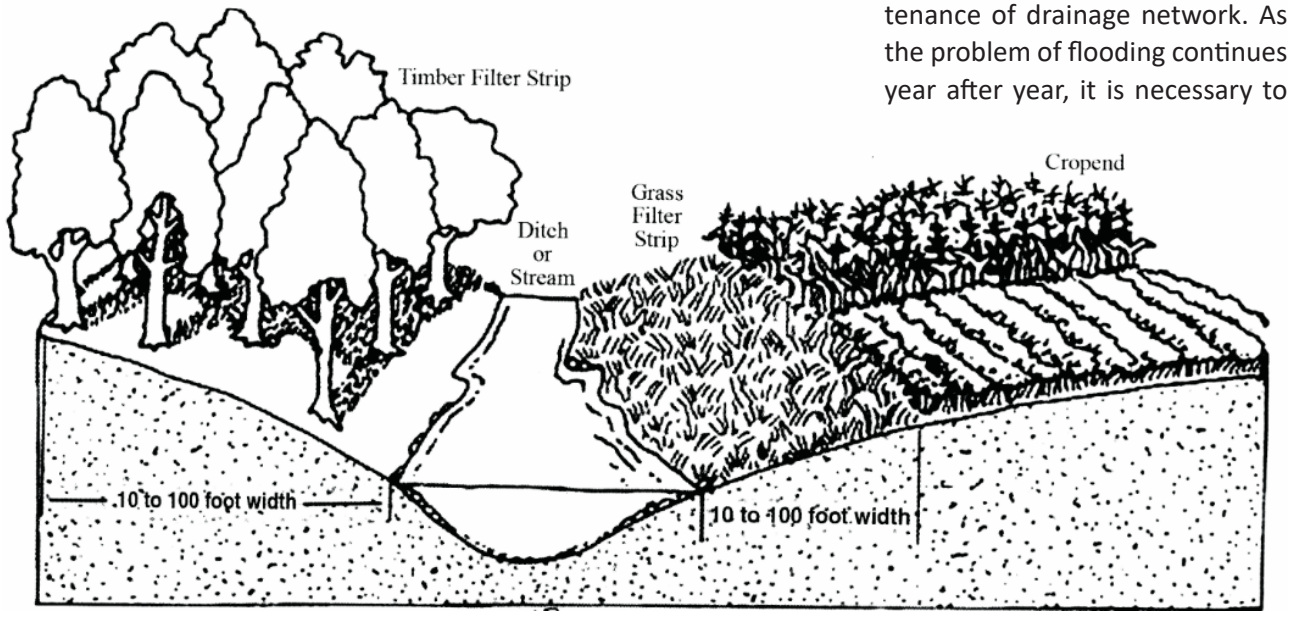


Fig. 12: Green filter strip along a Bio-Swale
Source: Jain A.K. (2021) Environment, Urbanisation and Development, Discovery Publishing House, New Delhi

Fig. 13: Step well (baoli) at Red Fort- a unique feature of traditional water system
Source: Author

think whether the paradigm of drainage needs to change which is more sustainable, nature based and integrated with water supply, sewage, solid waste management, recreational, transport infrastructure and land use (Fig.14).

Based on these principles, the strategies of sustainable urban drainage involve the following:

- Surface water moves through swales and filter trenches that removed entrained pollutants
- The peak river discharge is delayed and reduced with incorporation of retention basins, enabling storage of water for reuse.
- Storage in retention/detention pond manages flood, as well as ground water recharge.
- Infiltration of water to ground through infiltration basins and soakaways that improve the quality of water, decreases the discharge, and enables ground water recharge.

Existing water channels and nallas in urban areas can be used for continuous on-channel recharge of groundwater and transfer of water from these channels to various areas with the help of sluice gates. Continuous recharge takes place through deep holes on the channel floor. This requires computer modelling of channel capacities, transfer mechanisms, storage capacities, flood prevention and system operation.

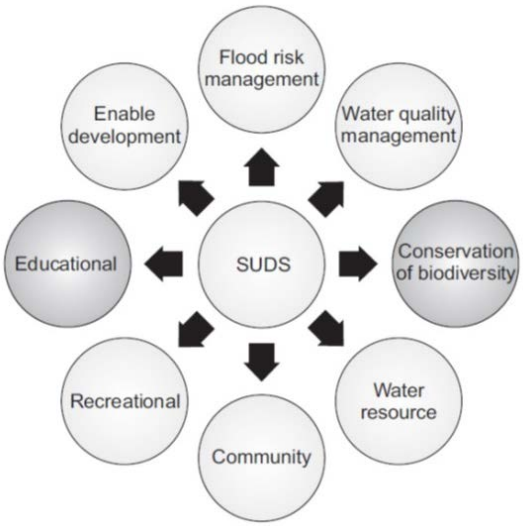


Fig 14: Sustainable Urban Drainage System (SUDS)
Source: Jain A.K., (2021) Environment, Urbanisation and Development, Discovery Publishing House, New Delhi

The cleanliness of the urban waterway can be maintained with the use of root zone system, green bridge, mosquito weed, guppy fishes to consume mosquito larvae, and aeration. The channel should be shaped, landscaped and deepened to increase the water storing capacity, wherever possible. Their banks can be the green lungs of city. While serving the function of on-channel groundwater recharge they also modify the micro-climate. The conjunctive use of groundwater along with on-channel recharge would also possible. Their use for water sports, recreation, water transport facilities could be possible. The existing dirty drains can be converted into attractive landscape trails and greenways, as planned in Dwaka (Najafgarh Drain, Fig. 15).

The Crisis of Traffic Congestion

Inauguration of 76 km long Urban Extension Road- 2 (UER- 2) by the Prime Minister Narendra Modi in August 2025 indicates India's economic prosperity and resultant motorization of the metropolitan area. It is often argued that such projects solve the problems of traffic congestion and trigger economic growth. While being proud that the vision of MPD 2021 has been implemented, some interlinked proposals have remained undeveloped. With a view to decongest Delhi more than 100 flyovers/underpass have been built, besides Urban Extension Roads (UER 2 and 3). With the completion of Delhi-Mumbai and Delhi-Dehradun Expressways, NHAI is working on two new links- a tunnel or elevated stretch from

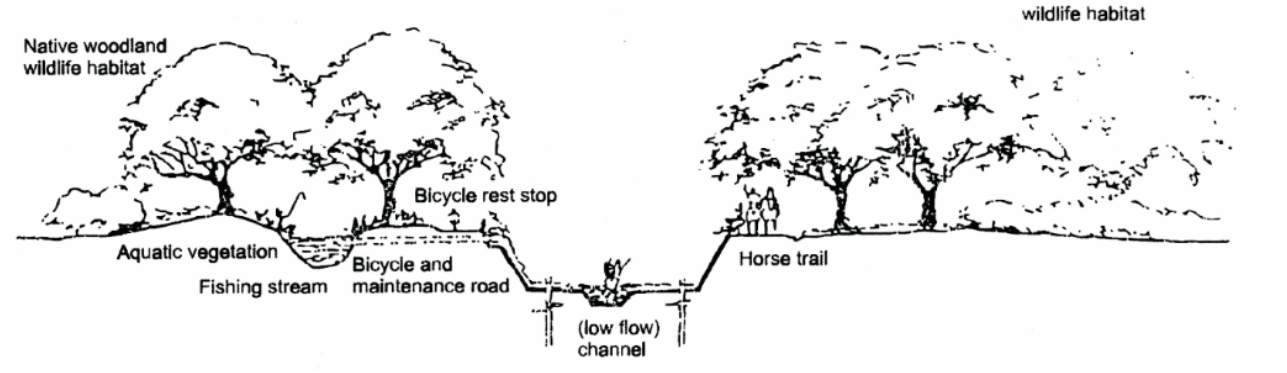


Fig. 15: Proposed landscape of Najafgarh Drain, Dwarka, Delhi)
Source: Jain A.K , Landscape Architecture, Discovery Publishing House, New Delhi

Sarai Kale Khan to the proposed INA- Nelson Mandela Mandir Marg elevated corridor and a tunnel from Gyarah Murti or Talkatora Stadium to the elevated corridor. These aim to tackle the congestion in Central Delhi. However, these projects may miss the bus in reducing the congestion. There is a need to develop a comprehensive vision to make Delhi a 15-minute city, as Paris and Barcelona are doing. These need not only urban restructuring but relooking at the basic concepts of land use for integrated traffic and transport planning. The multi-modal public transport is central to reduce traffic congestion, which is aimed at carrying 70 to 80% of trips in place of 30 to 35% at present (MPD 2021). It requires the provision of dedicated corridor for various modes of public transit, along all master plan roads and highways. Transit oriented development (TOD) needs meticulous planning and development of public land uses along the transit corridors.

As the transitional areas on the metropolitan shadow are experiencing faster population and economic growth, it is necessary to focus on preparatory spatial planning, protecting ecology, and rural-urban continuum by policy support for restructuring and sustainability at regional scale. The critics often accuse that the mega transit projects and highways benefits the car lobby and marginalise the pedestrians, cyclists and two wheelers/ intermediate public transit. The planners unknowingly support this phenomenon by providing extensive parking areas. This is visible in the new Combined Secretariat (Kartavya Bhavan) in the Central Vista, inaugurated by the Prime Minister Narendra Modi in August 2025. It was an opportunity to discourage private cars by not providing parking except VIPs/Emergency/ Security vehicles and link the new office complex by monorail/golf carts with the metro and bus terminals. Besides restricted parking, another low-cost solution is to gradually close the right hand turnings on major roads. Even if 50% of such turning are closed, it will contribute immensely in signal free traffic movement and reduce the congestion. Besides the public transit, (BRT, RRT and Metro), it is necessary to promote the para-transit, non-motorised transport,

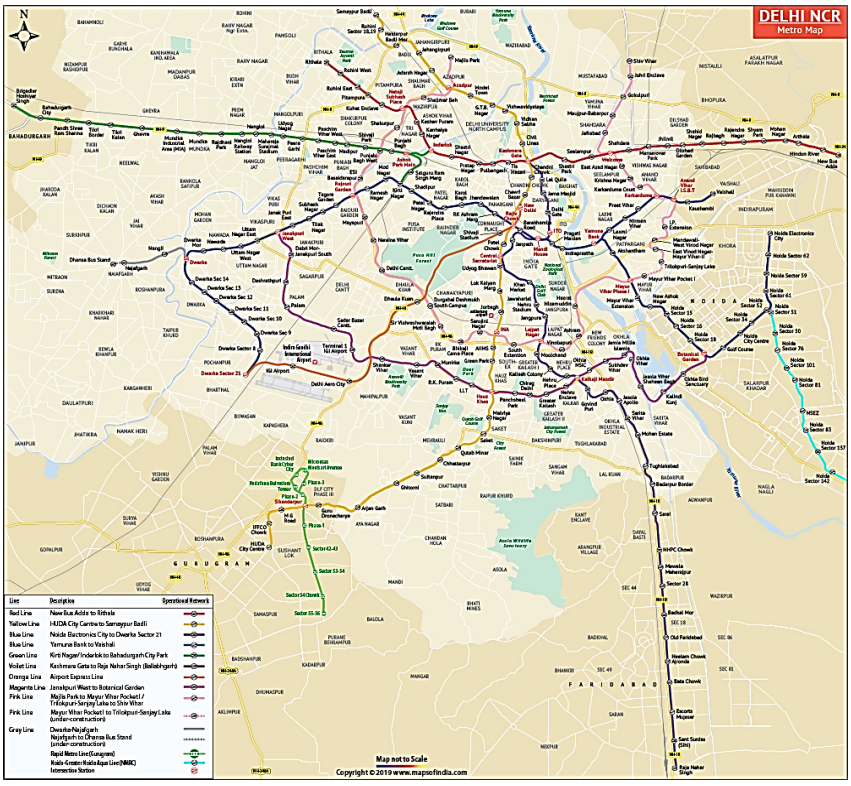


Fig. 16: Delhi Metro Network (2025)
Source: Delhi Metro Rail Corporation

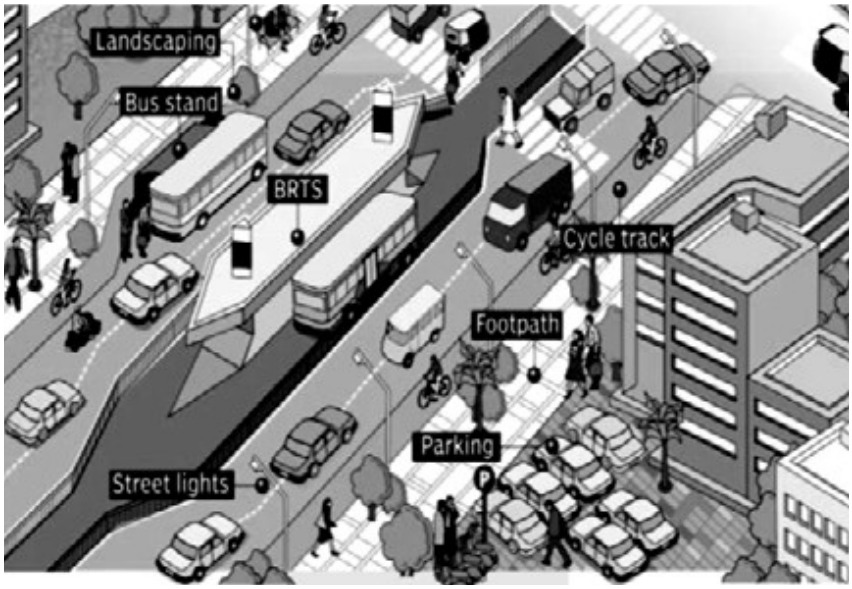


Fig. 17: National Urban Transport policy stresses upon dedicated footpath, cycle tracks, carriageways, and Bus Rapid Transit System with spaces for bus stops, street vendors, utilities, street furniture and parking

Source: DUAC/Amit Ghosal, Punjabi Bagh Ward No. 103, New Delhi

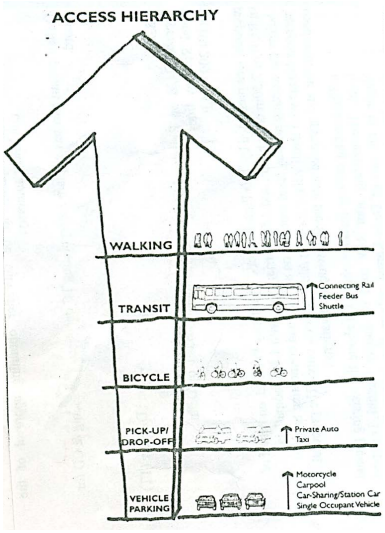


Fig. 18: Prioritise Walk to Work, Public Transport and Non-Motorised Transport Over Private Vehicles

Source: Jain A.K. (2014) Mobility Based City Planning and Design, ITPI Journal, Jan-March

Fig. 19: Street Design for Pedestrians

Source: UTTIPEC

and non-polluting, hybrid, hydrogen and electric vehicles (Figs. 16 to 18). Urban design approach can make the streets and roads with safer spaces for the pedestrians (Fig. 19).

The Crisis of Slums and Informal Settlements

About one-fourth of Delhi's population is living in about 675 slums and Jhuggi-Jhompri (JJ) clusters and 1800 unauthorised colonies. According to GNCTD Survey (2022) about 21.6 lakh people are living in about 4 lakh jhuggis /huts-ments and about 33 lakh people live in the illegal colonies.

In Delhi's planning parlance 'slum' is defines as an area unfit for human habitation. Slums are designated according to Slum (Improvement and Clearance) Areas Act of 1956. The notified slums are legal in status and are eligible to resettlement and range of services. Jhuggi-Jhompri settlements are seen as illegal encroachments on public and private lands. During the emergency (1975-77), a massive program of slum resettlement, covering 1.54 lakh plots of 21 sqm each (7 lakh people) living in the slums and Jhuggi-Jhompri (JJ) clusters was undertaken by the Delhi Development Authority (DDA). Touted as one of the world's largest slum resettlement projects, it attracted global attention and created controversies.

In 2016, the Delhi cabinet approved the Delhi Slum Policy, according to which no jhuggi which has come up before January 1,2006 will be demolished, and those staying in slums till January 1, 2015, are eligible for relocation. During the

Fig. 20: In-situ Slum Rehabilitation in Kalkaji Extension, 14 storied, 3024 flats 25sqm each, built by the DDA, inaugurated by the Prime Minister in November 2022

Delhi Assembly elections (2025) the Prime Minister Narendra Modi announced the policy of Jahan Jhuggi -Wahan Makaan for Delhi. The Delhi Development Authority's (DDA) in-situ project at Kalkaji with 3024 flats was inaugurated by the Prime Minister Narendra Modi in November 2023 (Fig. 20). Another project at Jailorwala Bagh with 1675 flats was inaugurated on 2nd January 2025. The Kathputli Slum Redevelopment Project covering 5.22 Ha of area with 2,800 flats in 14 storey towers for slum dwellers is nearing completion (Fig. 21).

It has been developed under the public-private partnership under the following norms of MPD 2021:

- Minimum plot size 2000 sqm (facing a min. road of 9m).
- Density – 600 to 900 units per hectare.
- The scheme should be designed in a composite manner with an overall maximum FAR of 400
- Mixed land use/commercial component up to 10% of permissible FAR.
- Specific situations may require clubbing of scattered squatters with JJ sites in the neighbourhood to work out an overall comprehensive scheme.
- The minimum component of the land area for rehabilitation of squatters has to be 60% and maximum area for remunerative use has to be 40%.
- Area of dwelling unit for rehabilitation shall be around 25 to 30 sq.m.
- Common parking is to be provided which can be relaxed wherever required, except for the parking for remunerative purposes.
- No restriction on ground coverage (except set-backs)
- There is no restriction on the height, subject to clearance of the Fire Department, Civil Aviation Department and Structural Safety. The development control norms facilitate both the options-walk up (5 storeys) or multi-storeyed apartments in order to achieve the full permissible density and floor area ratio.
- Schemes/designs should be compatible for disabled.

Fig. 21: Kathputli Slum Rehabilitation is based on principle of in-situ slum rehabilitation with an enhanced FAR of 400, of which 40% of FAR for market sale enables financing the construction of the dwelling units for slum dwellers

Source: DDA

In the unplanned areas, illegal colonies, the Master Plan of Delhi (MPD 2021) allows the amalgamation of the plots to a minimum combined area of 1670 sqm with an FAR up to 400 and a minimum street width of 7.5 m. that would enable the owners of fragmented plots to go for a composite redevelopment.

Balancing Providers and Supports Based Models: Delhi has moved from Site and Services (Supports Based Model) to Providers' Model of slum resettlement. John Turner in his 1976 book 'Housing by People: Towards Autonomy in Building Environments' wrote that "only a minority can be supplied housing in centrally administered ways using centralising technologies, and then only at the expense of an impoverished majority and the rapid exhaustion and poisoning of the planet's resources." Since 1972, more than 70% of all the World Bank's housing loans were for Sites and Services. However, it fell out of favour due to implementation issues. In 2022, the World Bank study 'Reconsidering Sites and Services' pleaded again for its revival. The greatest advantage of the site and services strategy is that it is rapid, low cost and provides freedom to the families to design their dwellings according to their needs, resources and tastes. As compared to the flats in a multi-storied building, the site and services schemes facilitate connections with the ground, so important for the children, women and self-employed. The allottees finance the cost of constructing their houses and part of the land cost, whereas the development agency provides the land and services. This way every house is an expression of the lifestyle of its dwellers, but within an organised

framework and municipal services. This can also act as a powerful tool of poverty reduction. As suggested by Jane Jacob, Hernando de Sato, Christopher Benninger and Graham Tipple, the small shops and micro- businesses are the symptoms of inclusive growth and empower the informal sector.

According to Jane Jacobs, *'Planning for vitality must aim at unslumming the slums and clarifying the visual order of cities and it must do so by both promoting and illuminating functional order, rather than obstructing and denying it.'*

Writing about the slum dwellers Christopher Benninger states: *'this needs support from the planning and housing agencies, both governmental and non-governmental, to enable them to always put the last person first, looking at the hutment dweller, the informal sector hawker, the physically challenged, domestic servants, rickshawalas, and casual workers. This requires seeking the paths and channels to support, facilitate and empower the poor citizens into becoming its stakeholders, thus harnessing their energies and amplifying their contribution. We need to examine the shelter, in a milieu where planning has safeguarded disproportionately for the elite segments of the society'.*

It is necessary to strike a balance between providers' and supports-based models. Apart from the DDA Site and Services, there are other examples of supports-based model. One of them is the Odisha government's Jaga Mission (2018) which provide land rights to impoverished families living in urban slums, under which 2.4 lakh families have been covered together with financial assistance to construct their own houses. The participatory local planning also helps in the integration of slums with city development plan, social welfare, organisational development, and income generation with linkages between the markets and informal sector. The strategy of using the resources and strength of the communities is the starting point where the communities plan and implement the projects themselves. The government takes the role of facilitator and supporter. Secure land tenure is the foundation of slum rehabilitation, whereby. the communities can negotiate their own tenure arrangements through strategies such as cooperative lease, land-swapping or user rights.

Instead of promoting a provider's development model for informal settlements, a range of options can be considered:

1. **Repairs, Rehabilitation and Retrofitting** for upgrading and improving the physical conditions and quality of life.
2. **Relocation** provides security through land use rights and buildings are be advantageous.
3. **Resharing of Land:** Land sharing mutually benefits both the landowner and the community living on that land. The community gets secure tenure via long term leasehold, and the people can design and develop/redevelop their housing, services and facilities.
4. **Reconstruction:** In this strategy, existing communities are rebuilt on the same land, the strategy allows people to continue living in the same area and to remain close to their places of work.
5. **Reblocking:** Reblocking is a systematic way of improving the infrastructure and physical conditions in existing communities by adjusting or installing the sewers, drains, walkways, parking and roads in such a way that ensures the continuity of the community. Some houses may have to be moved and reconstructed to improve access, or some lanes may have to be widened and realigned to enable power, drainage lines, water supply systems or sewers to be laid. Reblocking can bring illegal colonies into formal planning framework for composite development together with land tenure security.
6. **Support-Infill In-situ Resettlement:** The 'Support-Infill' process is based on the 3-dimensional skeletal grid, designed on a modular basis and utilising simple precast components, which permit large variations, adjustments, negotiations and extensions of the dwellings. The skeletal system does not require sophisticated machinery, plant and skills for its production and assembly. The conceptual framework of 'supports-based housing', is based on a detailed analysis and identification of the actors, domains, morphological and spatial relationships and components of housing development. The space modules are developed for variety of dwelling unit design which allow several permutations and combinations based on concept of domain and right of transformation the concept of differentiated responsibilities. The skeletal structure can ei-

ther be erected by the people themselves or by a centralised organisation (Figs. 22 and 23).

For most of the slum dwellers, livelihood is a major issue. As per MPD 2021, it is mandatory that mixed use resettlement plots are provided and 10% of the space in all shopping centres is reserved for street vendors and informal traders, in the form of vending stalls, kiosks and platforms.

In each option, the following plans are developed by collective local planning:

- Infrastructure development plans
- Environmental sustainability Climate and Disaster Resilience, Heat Mitigation Plans
- Social development plans
- Economic development.

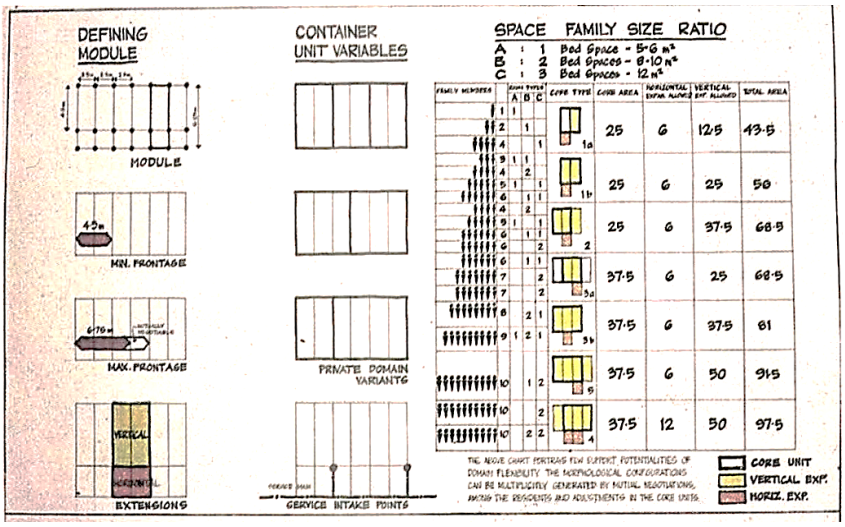


Fig. 22: Supports-Infill Design allows freedom, flexibility, and choices by participatory and evolutionary growth

Source: Author

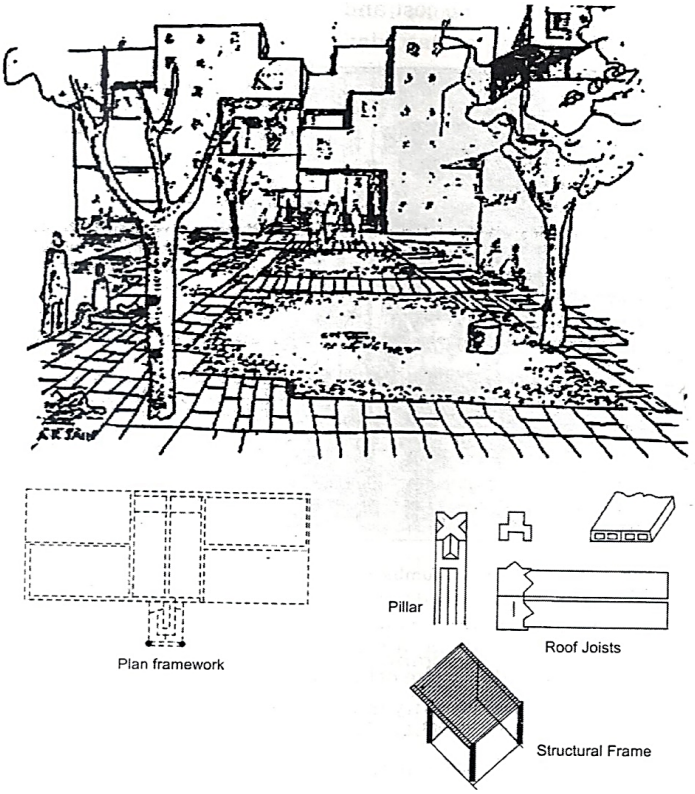


Fig. 23: Skeleton housing provides platforms with a wet core for expandable houses

Source: Jain A.K. Housing and Community Planning, Discovery Publishing House, New Delhi, 2020

As the city services are not immediately available in the slums and resettlement schemes, the alternative, packaged and self-contained units, such as Compact Water Treatment unit, Compact Sewerage Unit and Tunnel Reactor can be provided. To facilitate skill development a Building Centre can be a useful provision.

These options point out towards reviewing the present provider's model of Slum Rehabilitation by high-density, high-rise resettlement pattern. At least half of the slum housing and resettlement should be Support Based. The pattern of incremental slum plots proposed in the Draft Master Plan for Delhi (1959) needs be reconsidered and revived (Fig. 24).

The obsession of providing subsidy for slum rehabilitation has resulted into construction of pigeonhole flats and their illegal transfers. Many slum dwellers may prefer bigger non-subsidised plots, where the strength of the communities can be mobilised in the process of slum rehabilitation. In this strategy, the government takes the role of facilitator and supporter by providing land and land rights, creating building centres, building material banks, and tax/GST exemptions.

Conclusions

Delhi is facing huge urban challenges and crisis which include air pollution, climate change, river pollution and flooding, traffic con-

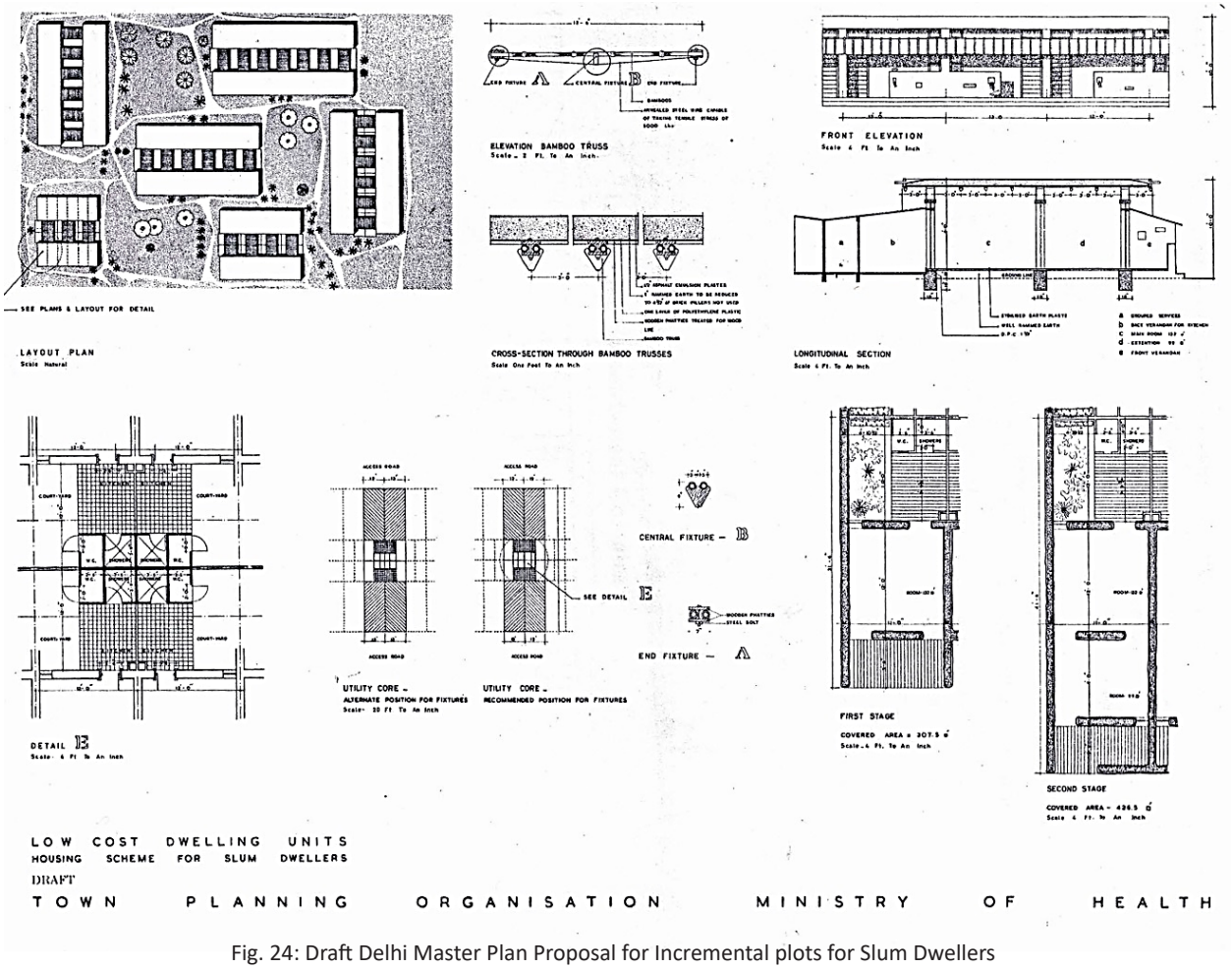


Fig. 24: Draft Delhi Master Plan Proposal for Incremental plots for Slum Dwellers

Source: TPO, Ministry of Health, New Delhi, 1959

gestion, slums and informal settlements. Response to these needs a shift from 20 year master plan to 5 year strategic planning, invoking circular, sustainable and resilient urban systems.

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Stakeholder Consultation on Green Public Procurement in Steel and Cement (GPPSC)

Organized a Stakeholder Consultation Workshop on Green Public Procurement in Steel and Cement (GPPSC) on August 19, 2025 at New Delhi in collaboration with GreenTree Global (GT Global). Session on Policy Imperatives for Green Public Procurement in Steel and Cement was chaired by Executive Director, BMTPC. With India producing nearly 144 million tonnes of crude steel and 426 million tonnes of cement annually, these two sectors together contribute a significant share of emissions. This makes green public procurement an essential lever for achieving our decarbonization and sustainability goals.

The workshop brought together senior government policymakers, industry leaders, knowledge partners, and global experts who shared perspectives on national commitments, market readiness, global best practices, and the way forward. The deliberations created a strong collective understanding of opportunities and challenges, and this initiative will help shape a clearer policy framework and market-aligned roadmap for sustainable procurement in India to make green public procurement a transformative driver of low-carbon growth in the construction sector. The consultation was moderated by Shri Anurag Bajpai, CEO, GT Blobal.

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Urban Crisis Response in the 21st Century: Innovations, Challenges, and Policy Imperatives

Dr. Janardan Singh Chauhan *

Introduction

India is at the center of one of the world's most dramatic urban transformations. Currently, about 35 percent of India's population lives in urban areas, and this figure is expected to cross 40 percent by 2035, adding nearly 400 million new residents to Indian cities by 2050. Urban centers already contribute nearly 70 percent of India's GDP, driving innovation, trade, and services. However, Indian cities also face mounting vulnerabilities.

Floods in Mumbai and Chennai, recurrent heatwaves in Ahmedabad and Delhi, water scarcity in Bangalore and Chennai, air pollution in Delhi NCR, and the COVID-19 pandemic have revealed the fragility of Indian cities. Most of these crisis are compounded by rapid, unplanned urbanization, weak governance, socio-economic inequality, and environmental degradation.

Urban crisis in India are no longer rare, one-off disasters. They are recurring, systemic challenges that threaten to undermine economic growth, human well-being, and sustainable development. Responding to these crisis requires innovation, structural reforms, and strong policy interventions that recognize the unique challenges of India's urbanization.

The Nature of Urban Crisis in 21st Century India

- **Floods and Waterlogging:** India's major metros have repeatedly faced devastating floods. Mumbai's 2005 deluge killed over 1,000 people, while the 2017 and 2019 floods paralyzed the financial capital again. Chennai's 2015 floods displaced nearly 1.8 million residents, and in 2023, the city witnessed another major flood due to Cyclone Michaung. Poor drainage, encroachment on wetlands, and unregulated construction are the key causes.
- **Heatwaves:** Rising temperatures and urban heat island effects have made Indian cities increasingly dangerous. Ahmedabad's 2010 heatwave killed more than 1,300 people. Delhi and Lucknow recorded record-breaking heat in 2022 and 2024. Climate change projections suggest longer, more frequent, and more severe heatwaves in the coming decades.
- **Air Pollution:** Delhi NCR remains one of the world's most polluted regions. Stubble burning in Punjab and Haryana, vehicular emissions, industrial pollution, and dust combine to create toxic smog every winter. Kanpur, Patna, and Lucknow also feature regularly on global air pollution rankings.
- **Water Scarcity:** Chennai's "Day Zero" in 2019 became a symbol of India's water crisis, as taps ran dry and residents lined up for hours to collect water. Bangalore faces similar threats due to rapid population growth, declining groundwater, and disappearing lakes. Smaller cities like Nagpur and Aurangabad are also under water stress.
- **Public Health Emergencies:** COVID-19 highlighted the vulnerability of Indian cities. Mi-

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grant workers in Delhi, Mumbai, and Surat were stranded without food or shelter, exposing gaps in social protection. Other health crisis, including dengue in Delhi and cholera in Kolkata's peri-urban areas, underscore the fragility of urban health systems.

- **Infrastructure Collapse:** Indian cities regularly witness flyover crashes, building collapses, and transport disruptions. These incidents reflect poor enforcement of building codes and corruption in construction.

Together, these crisis reveal the deeply interconnected vulnerabilities of Indian cities.

Innovations in Urban Crisis Response in India

Despite challenges, Indian cities have pioneered several innovative resilience measures.

1. Governance and Policy Innovation

The National Disaster Management Authority (NDMA) provides a national framework for disaster risk reduction. State Disaster Management Authorities (SDMAs) and municipal disaster management cells have been established in many cities. Odisha's cyclone preparedness model, which reduced casualties significantly, is recognized globally.

2. Heat Action Plans

Ahmedabad launched India's first city-level Heat Action Plan in 2013, introducing early warning systems, public awareness campaigns, and medical preparedness. The model has now been replicated in over 20 Indian cities, including Nagpur, Bhubaneswar, and Delhi.

3. Smart Cities and Technology Use

Under the Smart Cities Mission, cities like Pune, Surat, and Bhopal have established Integrated Command and Control Centres (ICCCs) for real-time monitoring and crisis management. GIS mapping, drone surveillance, and digital apps are increasingly used for flood management, traffic control, and health emergencies.

4. Green and Blue Infrastructure

Chennai has mandated rainwater harvesting for households since the early 2000s, though enforcement remains inconsistent. Pune and Hyderabad are experimenting with sponge city concepts. Delhi has taken steps to restore parts of the Yamuna floodplain to mitigate flooding. Urban forestry programs in Bangalore and Hyderabad aim to reduce heat islands and improve air quality.

5. Community-Based Responses

Kerala's 2018 floods highlighted the role of community participation. Self-Help Groups, local panchayats, and civil society organizations played a central role in relief and recovery. During the COVID-19 pandemic, community kitchens in Kerala and migrant relief initiatives in Delhi and Mumbai showcased the importance of citizen-driven resilience.

6. Financing Innovations

Pune became the first Indian city to issue municipal bonds in recent years to fund urban infrastructure. Ahmedabad has also mobilized resources through bonds. PPPs (public-private partnerships) are increasingly used for resilience projects, though access to sustainable finance remains uneven.

Challenges in India's Urban Crisis Response

1. **Fragmented Governance:** Indian cities often suffer from overlapping responsibilities between municipal corporations, state agencies, and central authorities. For example, Delhi's pollution crisis involves at least four states and multiple agencies, complicating response efforts.
2. **Weak Urban Local Bodies (ULBs):** Most ULBs lack adequate finances, technical capacity, and autonomy. Dependence on state and central transfers hampers proactive resilience building.
3. **Inequality and Vulnerability:** Slums and informal settlements house nearly one-third of India's urban population. These areas are disproportionately affected by floods, heatwaves, and health crisis, yet rarely feature in resilience planning.
4. **Financial Constraints:** Investment in resilience remains low. Disaster relief dominates budgets, while proactive resilience planning receives limited funding.
5. **Climate Uncertainty:** Indian cities face multiple climate hazards—floods, droughts, sea-level rise, and heatwaves—yet most cities lack localized climate data and projections.
6. **Policy-Implementation Gap:** Building codes, environmental regulations, and zoning laws exist on paper but are

frequently violated, often with political and financial complicity.

Policy Imperatives for Indian Cities

To ensure effective urban crisis response in the 21st century, India needs systemic reforms:

- **Empower Urban Local Bodies:** Municipal corporations must be given greater fiscal autonomy, skilled staff, and decision-making power. Capacity-building programs for disaster management are essential.
- **Mainstream Resilience into Planning:** Urban master plans must integrate climate resilience, ecological buffers, and blue-green infrastructure. Wetlands, lakes, and forests should be preserved as natural defenses.
- **Inclusive Resilience:** Policies should prioritize the needs of slum dwellers, informal workers, and vulnerable groups. Participatory planning must ensure their voices are included.
- **Leverage Technology:** Cities must invest in digital twins, AI-driven forecasting, and early warning systems. Integrated Command Centres should cover not just metros but also Tier-II and Tier-III cities.
- **Innovative Financing:** Resilience bonds, municipal bonds, and climate funds should be scaled up. CSR contributions and PPPs can help bridge resource gaps.
- **Strengthen Regional Collaboration:** Issues like air pollution and flooding cross city boundaries. Regional coordination among states and cities is vital.
- **Focus Beyond Metros:** While megacities attract attention, Tier-II and Tier-III cities are urbanizing fastest and need resilience strategies tailored to their context.

Conclusion

India's urban future is both a challenge and an opportunity. Cities like Mumbai, Delhi, Chennai, Ahmedabad, and Bangalore exemplify the multiple crisis that urban India faces—floods, heatwaves, pollution, water scarcity, pandemics, and infrastructure collapse. Yet, they also showcase innovations that can be scaled and replicated.

Ahmedabad's Heat Action Plan, Kerala's community-driven disaster recovery, Odisha's cyclone preparedness, and the Smart Cities Mission's command centers demonstrate that resilience is achievable. However, systemic challenges—weak governance, inequality, and underfunding—must be addressed urgently.

The 21st century demands a paradigm shift: from reactive disaster relief to proactive resilience planning. Indian cities must embed resilience in every aspect of governance, urban design, and community life. Only then can they safeguard human lives, protect the environment, and sustain economic growth.

Urban resilience is not merely about surviving crisis—it is about ensuring that India's cities remain vibrant, inclusive, and sustainable in the face of unprecedented challenges.

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Closing the Loop: Green Concrete as a Pillar of Urban Crisis Response

Dr Priyanka Kochhar [1] *Dr Gaurav Bhatiani* [2]

Introduction: Urban Crisis and the Concrete Dilemma

World Habitat Day 2025 comes at a moment when India's cities are facing crisis and convergence. The theme proposed by the UN-Habitat, *Urban Crisis Response*, underscores that cities are not just centres of economic growth but also the frontlines where climate change, conflict, and inequality collide. Infrastructure deficit, overcrowding, poor quality of life and environmental stress are no longer isolated challenges — they overlap and magnify each other, determining whether urbanisation strengthens resilience or deepens vulnerability.

Given a young and aspirational population, India is projected to urbanise rapidly, and the built form of its towns and cities will therefore need to expand. The planned and managed expansion will have profound implications for climate resilience, resource security, and social equity. The conversation about urban crisis and responses to it, therefore, cannot be separated from the materials and resources that enable and support this growth.

The use of concrete sits at the heart of this debate. It has enabled highways, bridges, metros, and mass housing projects that define contemporary India. But concrete production also contributes more than 7% of global greenhouse gas emissions (Global Alliance for Buildings and Construction, 2024; World Resources Institute, 2023; World Economic Forum, 2024) and exerts sustained pressure on scarce natural resources like stone and sand. This dual identity — enabler of growth and driver of resource use and emissions — makes concrete an unavoidable subject in discussions on resilience. The central question is whether India can revisit the production and use of concrete so that its urban growth is aligned with long-term sustainability and urban preparedness.

Concrete's expanding footprint and its risks

India has a significant reliance on concrete for various purposes. Affordable housing schemes, metro rail systems, expressways, and municipal infrastructure are all designed based on their use. With the government's ambitious targets for housing and infrastructure creation by 2030, demand is expected to grow rapidly. This will bring two major challenges:

1. **Embodied carbon:** Unlike operational energy, which can be reduced through efficiency measures or renewable energy, embodied carbon is locked into a building at the moment of construction. Each tonne of cement produced today releases CO_2 that will remain in the atmosphere for decades (IPCC, 2021), contributing to cumulative emissions and tightening India's remaining carbon budget (Centre for Science and Environment, 2022). Because over 60% of cement-sector emissions come from the calcination process (Schneider et al., 2021; World Resources Institute, 2023)—chemically unavoid-

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able with current production methods—these emissions are considered 'locked in' unless offset through carbon capture or removal technologies.

2. **Resource stress:** The extraction of sand and stone for concrete is already at unsustainable levels, leading to ecological degradation (Bendixen et al., 2019; Bhattacharya & Kaushal, 2022), groundwater depletion, and even local conflicts. Rising costs of raw material extraction further burden infrastructure development.

These twin challenges highlight why conventional concrete needs to be revisited to enable sustainable urbanisation going forward. A transformation is essential and urgent to enable sustainable growth coupled with resilience.

Defining green concrete: a suite of solutions

Green concrete refers to a suite of interventions designed to reduce the environmental footprint of conventional concrete while preserving its performance. Three key strategies are part of this approach:

- **Clinker substitution:** Cement is the most carbon-intensive component of concrete. Replacing a portion of clinker with supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast furnace slag (GGBS), refuse-derived fuel comprising paper, plastic, rubber, etc., produced from municipal waste, or calcined clays can lower process emissions and material requirements significantly.
- **Recycled aggregates:** Processing construction and demolition (C&D) waste into high-quality aggregates reduces demand for virgin stone and sand, conserving natural resources while cutting emissions associated with extraction and transport.
- **Structural retention and reuse:** Planning for deconstruction rather than demolition allows slabs, beams, and columns to be preserved and reused in different ways, and enhances recovery of other materials such as wood, glass, steel, etc., avoiding both the emissions of new production and reconstruction costs.

Together, these interventions—including high rates of clinker substitution, recycled aggregates, and mix optimisation—can reduce embodied carbon by up to 50% (Dong et al., 2024; Medeiros et al., 2022). They have been tested in various countries under different settings and have demonstrated consistent performance on strength, durability, and cost-effectiveness, i.e., they are ready for mainstream adoption.

India's early efforts and good practices

India has already begun to act on these principles, signalling recognition that C&D waste is a resource, not a liability. Early efforts include the 2017 Manual for Deconstruction Towards Recovery and Utilisation of Construction and Demolition Waste issued by MoEFCC with GIZ support, which provided a technical foundation for pre-demolition audits, material inventories, and logistics networks.

Since then, several promising pilots and initiatives have demonstrated the feasibility of circular construction:

- **Burari C&D waste recycling plant (Delhi):** India's largest facility of this kind, with a capacity to process 2,000 tonnes per day, located on 7 acres in Burari. It processes up to 90-95% of raw input waste, separating it into stone aggregate, coarse sand, interlocking paver blocks, tiles, and other construction products (Hindustan Times, 2023; MoneyControl, 2023).
- **Delhi's C&D waste plants network:** Besides Burari, Delhi has other processing plants in Shastri Park, Ranikhera, Bakkarwala, etc., with a combined capacity of around 5,500 tonnes/day, enabling the city to process about 1.5 lakh tonnes/month and approximately 18 lakh tonnes/year of C&D waste (MoneyControl, 2023).
- **Delhi Metro Rail Corporation (DMRC):** In Rohini, DMRC set up a facility to process 150 tonnes/day of C&D waste. This plant aims to recover and recycle about 95% of incoming material—including concrete blocks, broken bricks, rubble, soil, and reinforcing steel using wet-technology processes (Times of India, 2017; Swachh India, 2017).
- **Pimpri-Chinchwad, Maharashtra**: The Moshi C&D plant processes 200 tonnes per day using wet/dry processing technologies and recycles 95% of the water used (CFLO World, n.d.a).
- **Surat, Gujarat**: Surat Green Precast Private Limited's C&D waste processing plant has

a capacity of 300 tonnes per day, producing aggregates and precast products (CFLO World, n.d.b).

- **Ahmedabad, Gujarat**: Amdavad Enviro Projects Pvt Ltd's C&D waste recycling facility operates at 1,000 tonnes per day, processing approximately 1.67 million tonnes of C&D waste since its inception (Gujarat Samachar, 2024).
- **Mumbai, Maharashtra**: Brihanmumbai Municipal Corporation's Dahisar plant processes 600 tonnes per day of C&D waste, converting debris into reusable materials and providing free debris collection for small quantities (Free Press Journal, 2024).
- **Bengaluru, Karnataka**: BBMP operates units at Chikkajala (1,000 tonnes per day) and Bagalur (750 tonnes per day), recycling C&D waste despite challenges in utilisation and operational losses (Times of India, 2024).

Together, these examples illustrate that circularity in construction is technically and economically viable. However, they remain isolated efforts rather than systemic practice. To achieve nationwide adoption, there is a need for standardised policies, incentives, and infrastructure development to support the scaling of such initiatives across all urban centres.

Identified gaps in policy and practice

Even though there has been significant progress in Delhi and a few encouraging pilots in other states, several gaps remain:

- **Limited institutionalisation:** Pre-demolition audits are not mandatory, and digital registries for secondary materials are sparse.
- **Fragmented supply chains:** C&D waste recovery is largely dominated by informal operators with little integration into formal procurement systems.
- **No embodied carbon mandates:** The National Building Code and public procurement frameworks do not yet set embodied carbon thresholds.
- **Governance issues —** There is a significant challenge because of the informal market in construction materials that operates on cash transactions.
- **Illegal mining —** Many states, such as Uttar Pradesh, Madhya Pradesh, Bihar, etc., have reported a significant amount of illegal mining of materials such as aggregates and sand.

These are institutional challenges rather than technical barriers — India has the engineering capacity and market demand to implement solutions at scale.

International lessons: what is possible

Global experience offers valuable models for systemic reform in C&D waste management, drawing from both high-income and developing contexts to inspire scalable, context-specific strategies.

Singapore:

Under its Zero Waste Masterplan, launched as part of the broader Sustainable Singapore Blueprint, the country has established ambitious targets to achieve a 70% national overall recycling rate by 2030, with a strong emphasis on diverting construction and demolition (C&D) waste from landfills through advanced sorting facilities and incentives for material reuse (Ministry of Sustainability and the Environment, 2019).

This includes the "Clean Land" initiative, which integrates waste minimisation into urban planning and has driven C&D recycling rates to over 99% in recent years, though a slight dip occurred in 2024 due to lower overall waste generation from economic factors (Malba Project, 2024).

These efforts are supported by infrastructure investments, such as expanded Waste-to-Energy plants, positioning Singapore as a leader in resource-efficient urban development (Ministry of Sustainability and the Environment, 2024).

European Union:

As of September 2024, Ireland mandates that all public sector construction projects specify concrete with a minimum of 30% clinker replacement, using low-carbon alternatives such as Ground Granulated Blast Furnace Slag (GGBS) or fly ash. This policy, introduced by the Department of Enterprise, Trade, and Employment, aims to significantly reduce the carbon footprint of government-funded infrastructure. Additionally, the use of Environmental Product Declarations (EPDs) is required to ensure transparency and accountability in material selection. The guidelines also phase out the use of high-clinker Ordinary Portland

Cement (CEM-I) in public works projects (Government of Ireland, 2024; EcoCem Global, 2024; Philip Lee, 2024; Department of Enterprise, Trade and Employment, 2024).

These measures are part of Ireland's broader Climate Action Plan 2024, which seeks to decarbonise the construction sector and align with the EU's Green Deal objectives. Early implementations have shown that such policies can lead to substantial carbon savings without significant cost overruns, fostering markets for recycled aggregates and blended cements (ECOS, 2024).

Australia:

The Materials & Embodied Carbon Leaders' Alliance (MECLA) is a collaborative industry-government initiative in Australia aiming to achieve a 40% reduction in embodied carbon for all new buildings, infrastructure, and renovations by 2030. This goal aligns with national net-zero objectives and emphasises early-stage design optimisations, such as material substitution and modular construction. MECLA's efforts are supported by various stakeholders, including state governments and industry partners, and are managed by organisations like WWF Australia and Climate-KIC Australia (Climate-KIC Australia, 2024).

Low-carbon concrete trials: MECLA's initiatives have led to several successful trials of low-carbon concrete in major Australian cities:

- **Melbourne Metro Tunnel Project**: This project utilised over 97,000 cubic meters of pre-cast concrete segments, incorporating low-carbon mixes to reduce emissions and divert 90% of construction waste from landfills (Concrete Institute of Australia, 2024).
- **Boral's Recarbonated Concrete Trial**: In a pioneering effort, Boral produced concrete using recycled concrete aggregates that were recarbonated via carbon capture technology from its cement plant. This trial, conducted in Sydney, replaced 50% of natural coarse aggregates with recarbonated materials, demonstrating a viable pathway for using products from carbon capture and storage (CCS) technologies (Boral, 2024).

These trials have shown that low-carbon concrete solutions can be cost-comparable or incur only minimal additional costs, especially when integrated early in the design process.

South Africa:

In April 2025, South Africa's Council for Scientific and Industrial Research (CSIR), in collaboration with USE-IT Waste Beneficiation and Key Bricks, launched an innovative green building block made from 70% recycled materials, including crushed waste glass and construction and demolition (C&D) debris. This initiative addresses the country's annual 5–7 million tons of unmanaged C&D waste and the housing backlog affecting over 2 million households.

Key features of the green block include (CSIR, 2025):

- **Material composition**: The blocks are composed of 70% recycled content, primarily from crushed waste glass and C&D waste, making them 100% recyclable.
- **Design and functionality**: The interlocking design allows for easy assembly without the need for cement between layers. Each block features internal hollows that facilitate the installation of electrical and water pipes, reducing the need for cutting grooves and ensuring structural integrity.
- **Sustainability and cost-effectiveness**: This approach not only diverts significant amounts of waste from landfills but also reduces the reliance on conventional virgin materials, contributing to environmental conservation and cost savings.

A demonstration house constructed using these eco-friendly blocks was unveiled in KwaZulu-Natal on April 11, 2025. The project showcases the practical application of circular economy principles in addressing housing shortages and waste management challenges (Engineering News, 2025).

This initiative exemplifies how developing countries can leverage innovative solutions to tackle pressing issues such as waste management and affordable housing.

These international experiences demonstrate that while technical feasibility is proven, widespread adoption depends on enabling frameworks — including procurement guidelines that

reward low-carbon materials, updated standards that allow higher substitution rates, and institutional mechanisms that create predictable demand. It is this combination of policy, market incentives, and regulatory clarity that turns low-carbon concrete from an innovation into the industry norm.

A phased roadmap for India's urban resilience

Building on India's early initiatives in construction and demolition (C&D) waste management, such as the 2017 *Manual for Deconstruction Towards Recovery and Utilisation of Construction and Demolition Waste* (MoEFCC, GIZ, 2017) and successful pilots like the Burari recycling plant in Delhi, a phased roadmap can help transition from fragmented efforts to systemic adoption while strengthening urban resilience.

In the short term, mandatory pre-demolition audits for all metropolitan projects are recommended. These audits, coupled with public disclosure of findings, can generate clear demand signals for secondary materials and build market and technical capacity (GIZ, 2022). Additionally, introducing low-carbon concrete specifications in flagship public works, such as PMAY (Urban and Rural) and Smart Cities Mission projects, provides immediate leverage to scale low-carbon materials, following lessons from Ireland and Singapore, where public procurement successfully drove uptake of blended cements and recycled aggregates.

In the medium term, the establishment of municipal material banks and digital registries can ensure a steady supply of secondary materials, addressing the critical supply-side bottleneck observed in developing countries like South Africa. Enforcing BIS codes for recycled and low-carbon materials in public buildings ensures standardisation and reliability, reducing perceived risks among contractors and investors. Scaling procurement mandates across ministries and departments creates a unified demand driver, much like MECLA in Australia, which successfully coordinated government and industry action to achieve measurable reductions in embodied carbon (MECLA, 2024).

In the long term, integrating embodied carbon thresholds into the National Building Code can institutionalise accountability and signal predictable regulatory requirements to the industry, similar to EU member states embedding carbon limits in public procurement (ECOS, 2024). Operationalising regional recycling hubs and structured supply chains for secondary materials ensures that the market for circular construction is reliable and cost-competitive. Finally, mandating deconstruction clauses in all public tenders embeds circularity into infrastructure creation, fostering a culture of reuse and resource efficiency, as demonstrated by Singapore's "Clean Land" initiative.

This sequencing—from short-term pilots to medium-term capacity building and long-term regulatory integration—creates predictability for the industry, confidence for investors, and accountability for policymakers, establishing a robust pathway for India's low-carbon, circular, and resilient urban infrastructure.

Conclusion: Turning knowledge into action

World Habitat Day 2025, with its theme of Urban Crisis Response, reminds us that every tonne of concrete specified today will shape the climate resilience, cost efficiency, and crisis-readiness of our cities for decades.

India has already taken significant steps toward circular construction. The Burari plant in Delhi, established in 2009, has processed over 4.3 million tonnes of C&D waste (CEEW, 2019; Centre for Science and Environment, 2019), supplying IS-certified aggregates for new construction (CFLO World, n.d.c). Meanwhile, the DMRC has established a facility in Rohini that processes 150 tonnes per day of C&D waste, recovering and recycling around 95% of incoming material—including concrete, bricks, rubble, soil, and reinforcing steel—through wet-technology processes. These efforts are further reinforced by the Construction and Demolition Waste Management Rules, effective from April 2025, which mandate the use of processed C&D waste in large construction and road projects, targeting 50% recycling by 2026-27 and 100% by 2028-29 (Central Pollution Control Board, 2025). Together, these initiatives demonstrate that circular construction is not merely a technical possibility but a scalable strategy that delivers both economic and environmental benefits.

However, pilots alone will not deliver systemic change. Policy convergence across multiple levels of governance is critical to mainstream green concrete. At the national level, ministries such as Housing & Urban Affairs, Road

Transport & Highways, and Jal Shakti should embed low-carbon concrete requirements into procurement guidelines for PMAY, Smart Cities, and GatiShakti projects, creating consistent demand signals and encouraging industry investment. At the city level, urban local bodies can make pre-demolition audits a precondition for building permissions, linking approvals to material recovery plans, with programs like AMRUT 2.0 providing platforms to pilot and scale these interventions. Academic and research institutions must generate life-cycle data and performance assessments to guide BIS and NBC reforms, ensuring standards are evidence-based and technically robust.

The private sector also has a key role to play. Developers and contractors can treat material efficiency and low-carbon design as competitive advantages, supported by financial incentives such as credit terms linked to embodied carbon disclosure. Codifying higher proportions of supplementary cementitious materials (SCMs) and recycled aggregates, along with embodied carbon thresholds, in BIS and NBC standards will embed circularity into everyday construction practice.

The next five years are decisive. India can either lock in a resource- and carbon-intensive development pathway or create a future where infrastructure growth strengthens resilience, lowers emissions, and enhances resource security. Green concrete is no longer a niche idea — it must become the default. The time to act is now, and World Habitat Day provides the platform to commit to a national agenda that positions green concrete as a cornerstone of India's urban resilience strategy.

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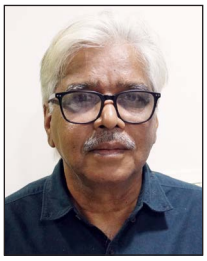
Eco-Innovation Training on Transforming the Built Environment Through Sustainable Building Materials - UNEP Initiative

Eco-Innovation Training Programmes on (i) Transforming the Built Environment through Sustainable Materials : Circularity in the Built Environment, July 9-10, 2025 and (ii) Transforming the Built Environment Through Sustainable Building Materials on April 28-29, 2025 were organised under the UNEP-BMZ project by UNEP in association with Bioregional UK, Global Alliance for Buildings & Construction & BMTPC.

The 2-days training dealt with actionable insights for sustainability in the building materials sector, covering life cycle thinking, circular economy strategies, and relevant Indian policies. Through interactive sessions and case studies, participants were exposed to tools for resource efficiency, material selection, and sustainable development. Participants were from Govt. agencies, startups, and manufacturers of innovative building materials and technologies. Decarbonisation of built environment is being dealt in the country through several internationally funded projects supported by Govt of India. These concerted efforts will pave the way to achieve India's Nationally Determined Contributions (NDCs).

Climate – Resilient, Zero – Carbon and Inclusive Cillages:

A Novel Habitat Model



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Introduction

Issues with urban development include inequality, environmental degradation, and climate – change vulnerability. Heatwaves are among the top three shocks, indicating how urgent the issue of extreme heat has become for cities. Inequality, a shortage of affordable housing, unemployment, and homelessness are becoming more and more pressing issues, and climate change remains the top stressor for cities. Life in cities is changing due to extreme heat as increased temperatures are making it more difficult for millions of people to make a living, go to school, get healthcare, and move around safely throughout the day, particularly in the rapidly growing cities and urban areas [1]. The lack of sustainable cooling and extreme urban heat are endangering productivity, escalating inequality, and raising the possibility of displacement when populations are unable to adapt. Extreme heat cannot be tolerated by cities as a seasonal annoyance. Heat is destroying livelihoods and overwhelm urban infrastructure and services without action. It is increasing migration, unemployment, and putting a great deal of strain on energy systems. Thus, cities need to take action to control increasing temperatures, before it's too late. It is expected that about 3.5 billion people will live in cities by 2050, making up 60% of the urban population worldwide. It is also more important than ever to direct the development and evolution of cities in the area to meet the requirements of people and the environment. The development issues are most noticeable in most of its cities. In addition to endangering our physical environment, climate change raises health hazards for urban areas, particularly for the most vulnerable communities of the economical, low- and middle-income urban population [1-3].

Cities must therefore, urgently meet the growing demand for adequate and inclusive housing, accessible basic services & infrastructure, energy, and mobility, in addition to addressing the challenges and impacts of climate change, and the rise in extreme heat, informality, food insecurity, economic instability, and poverty. In addition to making cities more vulnerable, these factors also reduce the resilience and coping mechanisms of cities, their local economies, and their residents [4]. When we think about cities, we usually see high-rises, roadways, and flyovers. However, the underappreciated resources of parks, lakes, and wetlands - known as blue-green infrastructure may be crucial in determining whether our cities are liveable as climate hazards like heat waves, flooding, and air pollution are worsening due to fast urbanization, making our cities more vulnerable than before. The blue-green infrastructure needs to be considered a necessary part of urban design and planning. As temperatures continue to rise and new climate thresholds are crossed, blue-green infrastructure, which includes from wetlands, water bodies to parks and tree -lined roads, is crucial to enhancing climate resilience. During heatwaves, it helps provide shade and thermal

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comfort, lower the urban heat island effect, and regulate hyperlocal temperatures in cities. In terms of ecology, it helps prevent flooding, absorbs rainfall, and promotes urban diversity [1-3].

In many cases, blue-green spaces represent an essential line of defense against climate shocks for vulnerable populations that have contributed least to the climatic catastrophe, and have the smallest social and economic safety nets. Access to cool rest areas and shade is also essential for the health of a significant portion of informal workers, who spend the majority of their time outside. Blue-green areas promote social cohesion in low-income neighbourhoods in addition to providing health and cooling benefits. If we are serious about creating resilient and equitable cities, we cannot ignore this nexus when talking about the vital role of blue-green infrastructure. For instance, planting trees is more than just aesthetics, as it contributes to better health outcomes, lower heat stress, enhances air quality, and even raises the local land value. However, various departments do not collaborate, it is reduced to this one-off activity. Rather than being considered essential infrastructure, blue-green spaces are still viewed as a luxury. The majority of cities like Delhi, Gurugram, Chandigarh, Pune, etc. flood when it rains. These cities have experienced flooding in recent years due to incessant rains.

In order to highlight the necessity of significant change given the urgency of achieving the various SDG goals by 2030 and reaching net zero emissions by 2070, urban resilience is defined as coping with and recovering from a shock by "bouncing back differently." There are fewer low-hanging fruits to pick in the shift to urban sustainability and resilience because many relatively easy and inexpensive changes, such as replacing streetlights with LED bulbs, or with solar lights, are already implemented in some of the cities in India. As technology develops and advances, incorporation of artificial intelligence into risk assessments has the potential to completely transform this process by enabling real – time building operational state evaluation and problem setting. This can guarantee the safety, effectiveness, and resilience of our nation's urban infrastructure by concentrating on the long-term maintenance of buildings. Smart technologies like IoT and AI can be used to improve efficiency, integrate green infrastructure and renewable energy, ensure inclusive planning with citizen participation, promote sustainable transportation, and implement resilient urban planning that considers climate risk when making decisions. Therefore, to develop smart, inclusive, climate-resilient and sustainable cities, a multifaceted approach to policy, planning, finance, and actions that take into account many economic, social, spatial, and environmental perspectives is necessary. This means creating small, compact, resource-efficient, green, inclusive, accessible and liveable cities as '*Cillages'* while also meeting the fundamental needs of city and urban residents. This paper proposes a concept of 'Cillages' - a new paradigm of habitat as an innovative solution and opportunity to overcome some of the aforesaid problems, obstacles and challenges [4 - 6].

Small, Compact, Green, Zero -Carbon, Inclusive, Accessible and Habitable Cillages: An Innovative Approach to Urban Crisis Habitat

The welfare of a city's most vulnerable populations is intrinsically linked to its resilience. For this reason, objective of creating 'Cillages' is based on a strong dedication to equity, which is more than simply a concept; as it serves the foundation for all the decisions and actions. In addressing the issues and challenges, by prioritizing the needs of front-line communities, making sure that all vulnerable groups are included in resilience planning, and tackling historical injustices that still influence the urban systems in which they currently live. *In order to promote economic, social, cultural, and environmental equity/justice for urban residents, the 'Cillages' can be designed to develop solutions that improve access to essential goods and services outside the existing tier I and tier II towns as suggested by the first and second authors during the 6th India International Science Festival the first and third authors 2020* [4 - 6].

Urban habitats and broader ecosystems that cities depend on is negatively damaged by resource extraction, excessive waste, and high emissions. By allowing cities to flourish within sustainable limits and develop resilience against both acute shocks and ongoing stresses, circular systems provide a resilient alternative for cities. A *'Cillage'* aims to increase the useful life of its urban assets and reduce the consumption of essential resources like electricity and water, in contrast to linear economies, which put a pressure on city systems with

waste and require constant fresh supplies. Cities that adopt circular concepts contribute significantly to national climate objectives in addition to achieving their emissions targets. *Therefore, in order to address the urgent problems and/ or pressing issues of excessive waste in the existing cities, 'Cillages' are proposed to be designed and incorporated into cities and urban areas.*

Electric vehicles, hydrogen and biofuels, green zones, e-auto registration and hydrogen bus certification will be given equal weightage in order to implement green mobility policies in Cillages'. Zero-emission zones shall be created in Cillages' if we aim to make roughly 50% of vehicles electric by 2030, surpassing the national goal of 30%, with required EV charging in new buildings, local battery manufacturing and recycling, and other buses with hydrogen fuels. Hence, these measures will lead to decrease emissions and improve air quality.

According to a research study by the first author at CSIR-CBRI Roorkee [7-8], a building in a composite climate, such as Delhi, Lucknow, Roorkee, Dehradun, Chandigarh, etc. can reduce its energy usage/ consumption by more than 50% by using passive design techniques/ strategies. Double glass, 40% WWR, shading elements like louvres and overhangs, a minimum wall thickness of 230 mm, storey height of 3.0m, green roofs, vegetation, water features, etc. are all part of the building, which reduces heat gain and glare while permitting natural ventilation and daylight penetration. Photovoltaic panels, other renewable resources and smart grids can be used to generate the remaining 50% of the energy needed on - site each year and that will lead to reduce carbon emissions. The market for air conditioners is expanding rapidly. India sold a record 14 million ACs in 2024. This number will be more than 28 million by 2030. The AC bears a large portion of the blame because cooling accounts for around 25-30 per cent of the country's peak energy load. The proposal to limit the temperature range for ACs nationwide to 20 to 28°C by Bureau of Energy Efficiency, and the government of India is a welcome step in this direction. The India Cooling Action Plan, which aims to cut overall cooling demand by 20-25% by 2037-2038, is closely related to it. The BEE data indicates that energy consumption increases significantly at very low set-points (18-22°C), by about 6% for every degree that the temperature is dropped. The change in energy use per degree is around 4-5% at the Indian human comfort level of 24-26°C and approximately 3% at 27°C and higher. Therefore, it's possible to create zero-carbon 'Cillages' using these aforesaid approaches [9].

There's a need to create adaptive policies and investments for 'Cillages' from future impacts by incorporating vulnerability mapping and climate risk assessments that meet a range of needs, by involving all locals in decision - making processes, especially vulnerable, and persons with disabilities and marginalized groups. To find synergies and avoid unforeseen consequences, a systems-based approach to 'Cillages' that connects sectors such as public transportation, water management, renewable energy, efficient housing must be adopted to equally meet the needs of everyone, especially those that are more inclusive and accessible environments.

Therefore, the following criteria must be met to achieve resilience in 'Cillages': (i) reducing the risk of climate change and disasters, including damage from natural disasters (such as earthquakes, cyclones, floods, heatwaves), while also preparing for future climate impacts; (ii) promoting social inclusion and equity by providing the most vulnerable groups with equitable access to infrastructure, basic services, and means of subsistence; (iii) integrating resilience into urban laws, development controls, master plans, and / or land use plans through cross-sectoral and multilevel governance; and (iv) environmental and infrastructure resilience to safeguard the planet and systems that embrace nature - based and locally driven solutions, such as focusing on ecosystem - based approaches and community engagements to build adaptive capacity and sustainability in order to for create cleaner and safer environments for all as 'Cillages' can absorb up to 75% stormwater and reduce peak temperatures by 6-8 degrees Celsius. Thus, to increase resilience in public spaces, water-sensitive planning techniques like micro-drainage and retention zones are needed. Therefore, in order to save lives in cities and major urban centres, climate – sensitive measures like vegetation, shading, and permeability are proposed in the 'Cillages'. Similarly, in order to future-proof our cities, reduce inequality, and guarantee that no one is left behind, we must achieve resilience in 'Cillages'.

According to a research study [10] by the first and third authors on "audit and rating of residential and educational buildings for ac-

cessibility – Indian Patents 2025," using a multilayered methodology for comprehensive assessment of accessibility requirements and standards, an accessibility rating score by combining parametric data metrics for quantitative and qualitative evaluations can be achieved. By employing advanced data analytics and machine learning algorithms, the audit and rating can adapt to evolving accessibility standards and user needs, providing real-time updates and recommendations for dynamic improvements. The green, public spaces and buildings can't be navigated by everyone, as older adults, and mobility - impaired groups/persons with disabilities face street -level hazards daily because of missing signages for way finding, visual and auditory, maps, road safety precautions including zebra crossings, STOP lines, signal crossings, traffic calming, and road signages, accessible toilets, inaccessible and faulty designs for physical infrastructure including approach, steps and stairs, ramps, handrails, tactile pavers, and other accessibility provisions for different types of buildings including residential, educational, institutional, assembly, business, mercantile, industry, storage and hazardous. Therefore, accessibility ensures spaces remain relevant, functional, and socially responsible across generations.

The App shall be used for the accessibility audit of all the buildings and correction measures shall be suggested for of a building's compliance to compliance to accessibility requirements and standards. The ultimate goal of these inventions is to increase awareness of and adoption of accessibility features in buildings and urban design of 'Cillages', so fostering a more inclusive built environment for all, irrespective of their physical abilities and disabilities. Therefore, accessibility must be included in the missing pillar of sustainability and urban design of Cillages.

Hence, the overall objective to create more resilient and sustainable built environments in India that promotes the health of everyone who interacts with them while guaranteeing their sustainability, functionality, use, and safety, and this is possible by developing *small, compact, inclusive, and accessible* '*Cillages*'. *In order to achieve all of the essential criteria of sustainability, the peri-urban development must be transformed into the idea of "Cillages - for a new habitat paradigm of sustainable and liveable cities," wherein a 'Cillage' of 10 kilometres is surrounded by urban villages or tier I and tier II towns outside the cities.* The habitat model for sustainability, space/population density, time regulation in daily life, economics of survival and prosperity, knowledge centre, social fabric and emotional coexistence, ecosystems to develop a decentralized economy, and multi-level first -generation entrepreneurs.

It is possible to develop the 'Cillages' concept in accordance with Physical Connectivity (PC), Electronic Connectivity (EC) and Knowledge Connectivity (KC) in order to achieve Economic Connectivity ($E_{co}C$), so that PC+EC+KC = $E_{co}C$. *In order to reduce migration and decongest cities,* Tier - I and Tier -II towns and *urban villages connect to cities from rural to urban and urban to rural, with a travel time of 20 to 30 minutes. Entrepreneurship needs to be the new focus of education; and ITIs and institutions that offer diplomas must be strengthened to offer and imparting training in a variety of skill sets that the country needs (KC + $E_{co}C$).* Sustainable design principles are crucial to contemporary architecture because they improve building occupant safety and well-being in addition to the health of the earth [4]. To put this concept into a real-time model, a site may be identified along major urban centres or cities for its detailed planning, urban design and execution.

Therefore, a 'Model Cillage' with an innovative approach to habitat must have high - density, low-rise (4 or 5 storey) development that contributes to decarbonize the energy used to operate buildings and reduce embodied emissions from the next generation of new, efficient and flexible buildings, using passive techniques, low-carbon building materials and smart energy systems, renewable technologies in order to achieve zero - carbon buildings in the 'Cillages' [7 - 8, 11-14]. Therefore, *if the proposed model is successful, this may be replicated by developing 2100 such 'Cillages'* in the first phase across the country in Tier - I and Tier -II towns and urban villages to *overcome the aforesaid, issues, challenges, problems and urban crisis with a public -private partnership or any other business model and can be funded by the central and state governments or world bank.* In keeping with the Viksit Bharat vision on self-reliance, innovation, and citizen empowerment, this will also play a major role in transforming the country into a developed nation by 2047, fostering an affluent, powerful, and technologically advanced India.

Conclusions, Recommendations and the Way Forward

Integrating the various elements and pillars of the global sustainable development agenda is necessary to build resilience for sustainable urban futures. Developing urban resilience is a complex, multifaceted, multi-sectoral, multi-stakeholder process that calls for a dramatic change /shift from previous approaches. In order to effectively build capacity for urban resilience, mainstreaming across local governments is required. An urban resilience roadmap is given to nations under the global sustainable development agenda. Thus, integrated urban planning is an essential component and pre-requisite for resilient 'Cillages' and accessibility must be considered as one of the pillars of sustainability. The other recommendations are:

1. The inclusive planning features of a 'Cillage' may include user profiles for residents, students, authorities, participatory planning interface (votes, feedback, surveys), accessibility tools (multilingual, voice input) to ensure all voices, are heard during planning.
2. In case of climate-resilient 'Cillages', the features may include GIS-based vulnerability mapping (floods, heat islands), real-time climate risk assessment tools, climate adaptation design templates (e.g., flood-resilient school designs) to ensure informed and climate-adaptive infrastructure decisions in 'Cillages'.
3. The features of renewable energy and smart grids may include rooftop solar potential estimator (based on satellite imagery), IoT-enabled smart meters and dashboards, smart grid integration suggestions for residential colonies and schools, solar and wind trees implementation along the open areas and public spaces to optimize energy usage and lower carbon emissions.
4. In case of sustainable transport, the features may include EV infrastructure planner (charging points, routing), bike and public transport integration, tracking of all persons, and persons with disabilities and car - pooling modules to reduce transport-related emissions and congestion.
5. In case of waste management (with e-waste geotagging), the features may include waste stream tracking (solid, organic, e-waste), smart bin management, e-waste geotagging system for efficient, tech-driven waste handling and recycling.
6. For technological innovation, the use of IOT for real-time monitoring (energy, water, air quality), AI for audit and inspection of built infrastructure and predictive maintenance of buildings, Big Data dashboard for city-level trends and alerts for smarter, data-driven decision-making.
7. The audit and rating of buildings shall be carried out for accessibility standards and user needs, providing real-time updates and recommendations for dynamic improvements to ensure that accessible spaces remain relevant, functional, and socially responsible across generations.
8. A model Cillage' must be developed having high - density, low-rise development using passive techniques, low-carbon building materials and smart energy systems, renewable technologies, including *affordable housing, blue-sky research and innovation labs for youth to experiment for developing innovative products and technologies*, in order to achieve zero - carbon emissions in 'Cillages' to meet the Government of India's net-zero target of 2070.

Thus, further investigations and research is needed to study the potential measurable advantages of 'Cillages' as sustainable cities for a new habitat model paradigm as an innovative solution and opportunity to overcome some of the aforesaid problems, obstacles and challenges.

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20th Meeting of Technical Assessment Committee of PACS

20th meeting of Technical Assessment Committee (TAC) of Performance Appraisal Certificate Scheme (PACS) of BMTPC was held on May 15, 2025. Following four new systems were awarded PAC after due deliberations & incorporation of comments :

1. Concrewall - Reinforced EPS Structural Panels (RESP) of M/s NBP Nirmaan Bharat Panels, MP
2. Building Lifting Technique - M/s Krishan Lal & Sons, Haryana
3. Indowud Natural Fibre Composite Products - M/s Indowud NFC Pvt. Ltd, Chennai
4. Insulated Sandwich Panel (Rigid Polyurethene/Polyisocyanurate Core) - M/s Suchi Foams Pvt. Ltd, Gujarat

Urban Crisis Response: Strategies, Challenges, and Lessons

Dr. Mala Singh *

Urban crisis - refers to a set of interlinked problems in cities infrastructure, environment, governance, social equity that are being worsened by climate change. Due to rapid & unplanned urbanization, cities are expanding quickly; many new residential / commercial developments are happening with weak planning or in hazard-prone zones (floodplains, low-lying coastal areas. TOI reported that Indian cities will require **$2.4 trillion by 2050** to withstand floods and heatwaves, citing World Bank estimates. ET Energyworld reported India faces a **$134 trillion challenge by 2070** to fund climate-resilient urban infrastructure.

A lot of urban infrastructure needed by 2030 is yet to be built; this provides both a risk and an opportunity: if resilience is not built in now, the exposure is huge. Climate stressors intensifying, Heatwaves are becoming more frequent; many cities are seeing increases in both daytime and nighttime temperatures. Urban Heat Island (UHI) effects make cities significantly hotter than surrounding rural areas. Rainfall is becoming more erratic: heavy bursts, flash floods, monsoon extremes. Drainage systems are often inadequate. Coastal cities face erosion, sea-level rise, cyclones. Infrastructure & services under strain, Drainage, sewage, water supply, road networks, waste management etc. are often old, poorly maintained, or not designed for climate extremes. Concretization of surfaces (roads, pavements, buildings) limits its natural absorption of rainwater and increases heat retention. Loss of open green space exacerbates flooding, heat, and poor air quality. Governance, planning & financial gaps are critical challenges, such fragmented governance: many agencies, overlapping responsibilities, weak coordination, especially across municipal, state, central levels local bodies (ULBs) often lack financial resources, technical capacity, staff, data.

Many cities do not have updated or approved master plans; even when master plans exist, climate risks are often poorly integrated. Social vulnerability & equity issues are quite visible, Poorer households often live in more hazard-prone areas (slums, informal settlements), with poorer housing and limited resilience to heat, flood, water logging. Health impacts due to heat stress, vector borne diseases, water borne diseases increase with flooding and poor sanitation are quite evident in such urban settlements. A big impact on the economic risks due to Loss of productivity (due to high heat days, infrastructure failure) and Costs of damage from floods and disasters rising. For example, urban flooding causes billions in losses.

As urban centres evolve and expand, their vulnerability to crises has significantly increased. From climate-induced disasters to public health emergencies, cities must adopt robust mechanisms for crisis response. In this article, we delve into the challenges faced by urban areas, especially in dense megacities like Mumbai, outline strategic responses, and propose a comprehensive roadmap for resilience. Urban crisis response

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is encumbered by numerous systemic, logistical, and socio-political obstacles. Firstly, the high population density associated with rapid urbanization leads to overcrowding, making evacuation and emergency services challenging. When disasters strike, the sheer volume of people can overwhelm existing infrastructure. Secondly, the presence of informal settlements—characterized by slums and unauthorized constructions—compounds these vulnerabilities, as many lack basic amenities and resilience features. Fragmented governance further complicates urban crisis response. Multiple agencies often have overlapping jurisdictions, which can lead to delays in coordinated action. The strain on aging infrastructure—such as transportation, drainage, and energy systems—makes cities even less equipped to handle emergencies. In coastal cities like Mumbai, climate vulnerability is heightened by urban heat islands, flooding, and rising sea levels, putting residents at greater risk. Additionally, gaps in data hinder timely decision-making, while social inequities mean marginalized communities often receive inadequate support when crises occur.

Strategies for Effective Urban Crisis Response

To navigate these hurdles, cities need to adopt effective strategies that can enhance their crisis response capabilities. A proactive approach to urban crisis management starts with planning and preparedness. Establishing a comprehensive crisis framework that incorporates input from various sectors allows for a coordinated response during emergencies. Investments in local infrastructure are equally crucial. Upgrading transport and drainage systems not only prepares cities for immediate crises but also contributes to long-term sustainability goals. The implementation of digital tools can revolutionize crisis management. Early warning systems that leverage real-time data enable quicker responses and inform residents about impending threats. Moreover, fostering community engagement is essential. Empowering local populations through training and partnerships not only builds resilience but also ensures that the voices of vulnerable communities are heard in policy discussions.

Roadmap for Urban Crisis Resilience

A phased roadmap can guide cities toward establishing robust urban crisis response systems.

- **Phase 1: Assessment & Planning-** involves conducting vulnerability mapping and risk assessments to identify areas at risk. This phase also requires the establishment of cross-sectoral crisis response frameworks.
- **Phase 2: Infrastructure & Technology-** focuses on upgrading existing systems, including drainage and energy provisions while investing in technological solutions to enhance early warning abilities and coordination efforts.
- **Phase 3: Community Engagement-** emphasizes building local capacity through training initiatives and developing inclusive policies for marginalized groups, ensuring equitable access to support during crises.
- **Phase 4: Policy Integration & Governance-** necessitates aligning climate action plans with disaster management strategies and creating legal structures that facilitate inter-agency cooperation.
- **Phase 5: Monitoring & Adaptation-** requires setting up feedback loops to ensure continuous improvement and utilizing data analytics to refine strategies based on lessons learned from past crises.

In conclusion, the pathway to resilience in urban centres like Mumbai is illuminated by these structured strategies and a commitment to adapting and progressing. By understanding the multifaceted challenges of urban crisis response and employing effective strategies, cities can safeguard their populations and ensure a sustainable future.

A Pilot case Study (To define strategy & road map for Climate Action plan)

History of Mumbai City -

Mumbai was originally an archipelago of seven islands—Bombay, Parel, Mazgaon, Worli, Colaba, Mahim, and Little Colaba. These seven islands underwent a series of land reclamations in the 19th and the 20th century. There is a history of Ecological Sacrifice: Embankments were built, hills were flattened, and the rubble dumped into marsh. It took over 200 years for Mumbai to become a continuous peninsula. These reclamations, however, happened at the cost of the city's coastal ecosystems — the mangroves, mudflats, coral reefs, creeks, and estuaries. Over the years, as Mumbai transformed into a thriving Trade & Business Center, it also became the center of India's

Climate Crisis. Mumbai is the most populous city in India and, globally, the 7th largest in terms of population. Projected to be the 6th largest by 2030 (UNDESA, 2018) it comprises two districts — Mumbai City and Mumbai Suburban. It plays host to a number of industries, multinational companies and important financial institutions. With a per capita income thrice that of the national average, Mumbai makes huge contribution to the total tax revenues of the country. The city is also an important international sea port and strategic from defense perspective. The most vulnerable section is also the slum dwellers and squatter communities in the city that comprise more than half of the total residents. According to the Slum Rehabilitation Authority (SRA), around 55% of Mumbai's population lives in slums and about 65% are employed in the informal sector (Bhowmik, 2010). This makes the impact and experience of climate risks highly varied across the city and across different socio-economic groups.

Mumbai's Key Risks – Sea Level, Flooding & Livelihoods-

- **Sea-Level Rise + Coastal Flooding:** Multiple reports (national & international) warn that large parts of Mumbai could be underwater by end of this century if sea levels rise unchecked.
- **Increased Cyclones & Storm Surges:** Changes in sea temperature are increasing likelihood of cyclones in the Arabian Sea (previously rare).
- **Frontline Communities under Severe Stress:** Koli fisher's traditional residents & fishermen.
- **Intensification & Compound Events:** Extreme rain events are growing in intensity & unpredictability; monsoon flooding becomes worse in low-lying suburbs. The Events like 26 July 2005 (very heavy rainfall) illustrate how existing drainage infrastructure fails; damage enormous.
- **Loss of Livelihood & Human Costs:** Mumbai has experienced significant and alarming loss of green cover, with some studies indicating a reduction of over 40% in the last few decades due to rapid urbanization, infrastructure projects, and construction. This decline has resulted in rising temperatures, health impacts like increased heat-related illnesses, and a loss of biodiversity. Efforts are underway to reverse this trend through initiatives like the Mumbai Climate Action Plan (MCAP), which focuses on scientifically increasing native green cover to mitigate these negative consequences.

Key Statistics and Figures

- **Overall decline:** Urban green cover in Mumbai reduced by approximately 40% over 30 years, from 1988 to 2018.
- **Recent loss:** Between 2016 and 2021, Mumbai lost about 2,028 hectares of urban tree cover.
- **Built-up area growth:** The city's built-up area increased by 66% between 1991 and 2018.

Consequences of Loss

- **Climate Change:**

  Loss of green cover has led to a sharp rise in land surface temperatures and contributes to urban heat island effects.

- **Health Impacts:**

  Residents face increased risks of heat-related deaths, respiratory difficulties, and other health issues.

- **Environmental Degradation:**

  There is a loss of local biodiversity and reduced carbon dioxide absorption.

- **Increased Flooding Risk:**

  The absence of tree cover and natural infiltration increases rainwater runoff, raising the risk of flooding.

Increasing Water Demand & other Challenges of Mumbai City

The potable water supply to Mumbai has increased by 16.17 percent since 2014, from 3,400 MLD to 3,750 MLD after 2014, 3,850 MLD after 2018, and 3,950 MLD in 2023. The demand for potable water will increase in the next two decades, straining the existing water sources. According to official projections, Mumbai will need 5,320 MLD or 34.6 percent more water by 2031 and 6,424 MLD or 62.6 percent more water by 2041, attributed mainly to the conversion of more slums and chawls to residential buildings through the state government's Slum Rehabilitation Scheme, enhanced floor space index (FSI) resulting in a proliferation of high-rise buildings, and increased migration and floating population.

- **Low Recycling Rate:**

  The current recycling rate is extremely low, with only a small fraction of the total treated water being recycled.

- **Discharge Mandate:**

  Following a National Green Tribunal order, the BMC is re-

quired to phase out discharging wastewater into the sea and adhere to strict effluent discharge standards.

- **Long-Term Goal:**

  The city aims to meet its Sustainable Development Goal (SDG 6) by proactively treating and reusing used water to ensure sustainable water availability for all by 2030.

A positive direction -The Mumbai Development Plan 2034 has demarcated these ecologically sensitive areas, such as forests, mangroves, waterbodies and areas under the Coastal Regulation Zone-I, as natural areas where no building development is permitted.

Waste Management Challenges in Mumbai

Mumbai produces a substantial amount of solid waste daily, with estimations ranging from around 7,500 to over 11,000 metric tons. Overburdened Landfills: Primary dumping grounds like Deonar and Kanjurmarg are operating beyond their capacity. Insufficient Processing: A large percentage of the generated waste, especially organic and construction waste, remains unprocessed and ends up in landfills or the sea.

- **Inadequate Slum Coverage:**

  Waste management systems often have poor coverage in slum areas, leading to environmental degradation and health risks for residents.

- **Marine and Water Pollution:**

  Human waste and leachate from landfills are released into the Arabian Sea, polluting the water.

- **Air Pollution:**

  Open burning of waste, a practice due to lack of proper disposal, contributes significantly to air pollution, especially particulate matter.

Consequences -

- **Environmental Degradation:** Land, water, and air are severely affected by waste accumulation and pollution.
- **Health Risks:** People living near dumping sites face health risks from air and water pollution, including exposure to heavy metals.
- **Strained Infrastructure:** The sheer volume of waste overwhelms existing waste management infrastructure.

Air Pollution Scenerio in Mumbai

WRI (World Resources Institute) India has identified key air pollutants in Mumbai, including particulate matter (PM2.5 and PM10) and nitrogen dioxide (NO2), mainly from vehicular emissions, construction dust, and industrial sources. Major Pollutants: WRI's analysis, as part of the Mumbai Climate Action Plan (2021), identified PM2.5, PM10, and NO2 as the primary pollutants. Primary Sources: Vehicular emissions, construction dust, and industrial units are significant contributors to Mumbai's air pollution. Seasonal Trends: Pollutant concentrations tend to increase during the winter months (November to February) due to lower temperatures. Air Pollution Hotspots: Analysis has identified areas in the central and southeastern parts of the city as hotspots for PM2.5 and NO2, often lacking the influence of the sea breeze. Focus on Solutions: WRI has supported Mumbai in its broader climate challenges, including air pollution, and has hosted forums like 'Unmukt Mumbai' to foster collaboration and discussion on effective air quality management practices.

Current Carbon Challenges in Mumbai

Mumbai's per capita emissions are significantly higher than the Indian national average. Factors contributing to these emissions include rapid industrialization and population growth, leading to increased demand for construction and amenities. The electricity sector is a major contributor, accounting for a large portion of the city's greenhouse gas emissions.

Mumbai's Climate Action Plan

Making climate change a priority, Mumbai signed the C40 Cities Deadline 2020 commitment, that aligns with the Paris Agreement, to reduce greenhouse gas (GHG) emissions to net zero by 2050. Mumbai's commitments also support the Government of India in achieving the Nationally Determined Contributions (NDCs) and are in line with the Government of Maharashtra's Majhi Vasundhara Abhiyaan, the Race2Zero campaign and other welcome policy initiatives towards sustainable and climate resilient development in Maharashtra.

MCAP is Mumbai's first comprehensive climate roadmap, launched in March 2022 by the Maharashtra Government & Mumbai's Municipal Corporation (Brihanmumbai Municipal Corporation, BMC / MCGM). It was developed in collaboration with knowledge-partners including World Resources Institute (WRI) India and C40 Cities. Purpose of this action plan was - To make Mumbai climate

resilient via both mitigation (reducing greenhouse gas emissions) and adaptation (preparing for climate risks such as floods, heat, coastal threats). The plan covers a 30-year horizon with short-, medium-, and long-term goals. Key Targets were committed for Net-zero emissions by 2050 for the city

The Mumbai Climate Action Plan (MCAP) is based on three assessments:

1. 'The Climate and Air Pollution Risks and Vulnerability Assessment' that places the issues of increasing risks and vulnerability in Mumbai city in the global context of climate change. Parameters considered were- Urban Heat Risk, Urban Flooding Risk, Landslide Risk, Coastal Risks & Air Pollution Risk. Parameters for Vulnerability risk were – Socio economic aspects, Physical Environmental Aspects & Infrastructure/Service Aspects.
2. The Green House Gas (GHG) inventory that identifies key sources responsible for emissions. The Greenhouse Gas (GHG) Inventory for Mumbai includes an analysis of sectors and sources that emit Carbon Dioxide, Methane, Nitrous Oxide and sinks that absorb (or sequester) GHGs from the atmosphere. This inventory will enable Mumbai to build evidence-based mitigation actions and policies and monitor progress. Critical Sources In 2019, Mumbai's GHG emissions were 23.42 million tons CO2 e of which, the Stationary Energy sector is responsible for 16.9 million tons CO2 e (72% of total emissions). Most of the city's emissions come from energy use in Residential buildings followed by commercial buildings and transport. Electricity consumption contributes significantly to total emissions (64.3%), due to the city's predominantly coal-based grid.
3. An inventory of natural green cover in the city that can Sequester Carbon Dioxide (CO2) The MCAP's core objective is achieving net-zero emissions by 2050, primarily through transitioning to renewable energy, promoting electric vehicles and public transportation, and building flood-resilient infrastructure.

Some of the key strategies

- **ENERGY EFFICIENCY AND RENEWABLE ENERGY:**
- **GREEN BUILDINGS:** Encouraging energy-efficient building practices and promoting the use of renewable energy sources contributes to lower emissions.
- **Low-Carbon Electricity:** Investing in low-carbon electricity is a core part of the strategy to decarbonize the city's energy supply.
- **SUSTAINABLE MOBILITY:**
- **Electric Vehicles:** Promoting the use of electric vehicles and transitioning to zero-emission public transport is crucial for reducing emissions from the transportation sector.
- **CLIMATE-RESILIENT INFRASTRUCTURE:**
- **Flood-Resilient Infrastructure:** Improving drainage networks and building flood-resilient infrastructure helps protect the city from the impacts of climate change, which indirectly contributes to overall sustainability.

Some of the specific strategies and flagship initiatives include:

- Decentralization of waste management (ward-level), with emphasis on organic waste composting, recycling, and reducing reliance on large dumpsites.
- Urban greening: increase vegetation cover, enhance biodiversity, make more open green space accessible, promote tree planting, green roofs/walls.
- Water management & flood resilience: improving drainage, early warning systems, rainwater harvesting, reuse of water, dealing with coastal flooding risk.
- Building energy efficiency: promoting green buildings; retrofitting of older buildings; integrating renewable energy in buildings; using cool roof / heat-resistant materials.
- Sustainable/clean mobility: pushing for electric vehicles, better public transport, less carbon from transport sector.
- Air quality monitoring and interventions to reduce pollutants.
- Institutional steps: A dedicated Environment & Climate Change Department was set up by BMC; climate budgeting has been instituted.

Progress & Implementation So Far

- Mumbai has already enacted some pilot / early projects under MCAP. For example: nature-based solutions, greening vulnerable neighbourhoods,

citizen-led tree planting etc.

- The city produced its first Climate Budget Report (FY2025-26), integrating MCAP targets into financial planning. Mumbai's Brihanmumbai Municipal Corporation (BMC) released its Climate Budget Report for Financial Year 2025-26 on World Environment Day, June 5, 2025, allocating ₹16,321.33 crore, or 37.81%, of its capital expenditure for climate-aligned projects, a significant increase from the previous year. The budget focuses on areas such as -Water Management, Green Infrastructure, Waste Management, Electric Mobility, For integrating the Mumbai Climate Action Plan (MCAP) into municipal spending.
- 29 agencies are now involved in MCAP implementation across different departments (Fire Brigade, BEST, Port Trust, etc.).

Gaps & Challenges

- Implementation is always harder than planning: many of the MCAP goals are ambitious and will require sustained resources, enforcement and political will.
- Measuring progress: need for strong monitoring & evaluation, data collection, transparency.
- Scale: For example, increasing green cover to 30-40% by 2030 is a big leap given current built-density and land constraints.
- Financing: Some projects need large capital investments (e.g. renewable energy, flood resilient infrastructure) plus long-term maintenance.
- Inclusivity: making sure vulnerable populations (slum dwellers, low-income groups) are not left behind, especially for housing, mobility, flood risk etc.

Key Suggestions to achieve the goals of Climate Action –

- Awareness among communities & their strong participation is the need of the hour.
- Financial mechanisms form the backbone of sustainable urban development, creating powerful market incentives that drive private sector engagement in green initiatives. These tools leverage municipal authority to reduce financial barriers and create attractive investment opportunities.

Market incentives for green incentives may prove a game changer, some examples are as under-

- Municipal Green Bonds
- Green Development Loans
- Property Tax Rebates
- Green Mortgages
- Transferrable Development Rights
- FAR/FSI Bonuses
- Expedited Consenting
- Fast Track Approvals
- Reduced Development Charges
- Performance Based Grants
- Green labelling Benefits
- Community Impact

& many more…….

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Special Session on Vulnerability Atlas of India at IMD

A Special Session on Vulnerability Atlas of India in hybrid mode was organised by India Meteorological Department (IMD) to celebrate 150 years of its establishment at New Delhi on January 8, 2025.

Disaster Preparedness and Lessons from Previous Disaster Rehabilitation Works

Dr. Deepak Bansal [1] *Ms. Yashika Bansal* [2]

India is highly vulnerable to many natural as well as man-made disasters like, Landslides, Cyclones, Earthquakes (EQ), Cloud Bursts, Floods, Droughts, Tsunamis, Lightening, Ground Subsidence, Forest Fires, Chemical/Gas leakages, Pollution, Major Accidents, Building/Infrastructure collapses, etc., which takes lots of lives and damages infrastructure worth billions of Indian Rupees every year. India had witnessed few major disasters like Latur Earthquake, Bhuj Earthquake, Orisssa Super Cyclone, Annual Floods, Landslides/ Cloud Bursts in UK, HP and J&K, Tsunami in T.N., Kerala & Andra Pradesh, etc. These disasters not only affects daily life of the public, but hamper growth of Indian economy. New Zealand is an example, where few earthquakes have brought the growth of their econ omy in negative figures. It is always better to create safe and resilient infrastructure, which cost only slightly more than conventional construction than incurring heavy cost & efforts in dealing with unsafe built infrastructure related devastation. There was a study by few international agencies, which found that the cost of developing safe infrastructure is a fraction of cost of rehabilitation works post disaster.

The disaster preparedness for earthquakes & cyclones can be taken care of, to a large extent by construction materials and construction systems, but construction materials/ techniques can not alone take care of Landslides or Cloud bust or Tsunami or Floods. These can be managed through proper Land use planning & defining zoning of the land and by incorporating them in building planning & building bye laws of the States/UTs. The Vulnerability Atlas of India, published by BMTPC (Building Materials Technologies Promotion Council)New Delhi, has given detailed vulnerabilities of places at district level and has also given appropriate suggestions/ guidelines in this regard. Some of the planning norms for designing safe infrastructure is represented in Fig.1.

Good amount of knowledge is available in technical literature & Building Codes prescribed by Bureau of Indian Standards (BIS) India, to identify, plan, design and desired type of construction in dealing/managing with these disasters and we just need to act to safeguard lives & properties from these disasters in advance. Hudco (Housing & Urban development Corporation Limited) Delhi, has done quite commendable work in post disaster reconstruction works on pan India basis in places like Chamoli (EQ), Latur (EQ), Jabalpur (EQ), Uttarkashi (EQ), Orissa (Cyclones), Gujarat (EQ), Andhra Pradesh (Floods), Tamil Nadu (Tsunami), Kerala (Tsunami), Jammu & Kashmir (EQ), Leh (Cloud Burst) and many other places. Hudco has provided consultancy services and also undertaken few demonstrative constructions using local construction materials & construction technologies involving beneficiaries in safe construction in the disaster affected areas. In-fact Hudco has given consultancy in other countries like in Sri-Lanka in planning, designing and construction of 50,000/ houses in Jaffna area of Sri-Lanka through UN-HABITAT incorporating local construction materials & technologies in scientific ways.

In Ladakh, which is also known as cold desert, the general typology of the houses is small houses with low height (ceiling to flooring), with walling/masonry constructed with mud or sun dried adobe and roofing is constructed with local wooden members with mud & thatch as roofing sheet, as there is no/scanty rainfall (till few years back).

These new houses in Ladakh, were constructed with stabilized

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Fig. 1: Some illustration to plan and construct safe buildings (As taken from NBC of BIS & HUDCO)

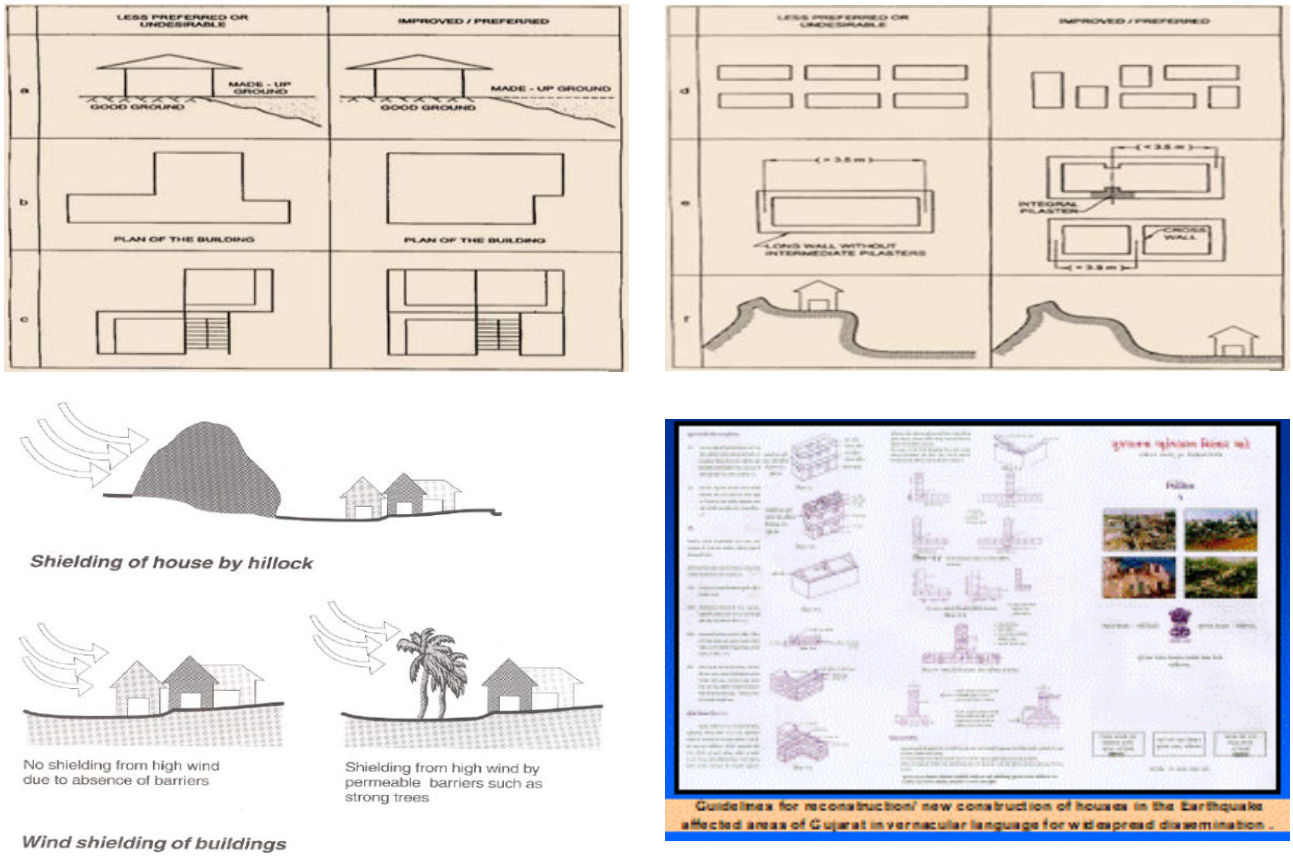
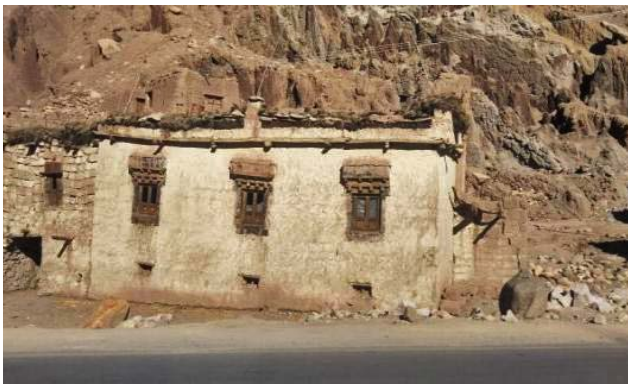


Fig. 2: Few Photographs of post disaster rehabilitation work done by HUDCO in GUJARAT & ORISSA.

Fig. 3: Houses in Ladakh: Traditional Houses



earth blocks, manufactured by pressing good earth & stabilizer (3-5% of cement) with optimum water content in mould in a hydraulic machine and used in walling/masonry with metal sheet roofing over which insulation in the form of thatch was provided . The stabilized soil blocks were locally made, so that locals can get on the hands training and can replicate this system. The general conditions of these houses are still good as visited in year 2025 and now, since there is a climate change happening globally and Leh is witnessing rain fall quite often, people are making soil stabilized blocks (as adobe blocks are not at all water resistant) locally and using them in the construction of their houses with roof projections to protect walling/masonry from rain as fired clay bricks are not available and other substitutes like cement concrete blocks (hollow/solid), AAC blocks are also not available or are very costly. These blocks are sustainable and energy efficient as well as NBC compliant as these blocks are covered in IS 1725.

Cloud bust & Landslides are a relatively a new phenomenon in terms of frequency and intensities, which is happening quite often with more and more severity, especially in the hilly States/UTs of Uttarakhand, Himachal Pradesh and J&K, and this is happening due to global warming related changes in local climate relates reasons and

Fig. 4: Houses in Ladakh: Engineered Houses with local soil using stabilizers like cement/lime

Fig. 5: Image of the Cloud Bust taken from Google:

we must find a durable & sustainable solution against this disaster as this bring immense rainfall in short duration, which causes flooding, road rutting/washing off, ground sinking and cutting of all infrastructure to the affected areas.

There has been extensively damage from cloud bursts and there is little or no warning for this disaster to escape the fury of this.

New Construction Techniques promoted and implemented by HUDCO in the Past

Hudco has been on the forefront in providing affordable & sustainable housing solutions to all sectors (EWS, LIG, MIG and HIG) all over the country with aesthetic & functional designs which conform to all the Indian Standards as well as local building bye laws involving beneficiaries. Hudco promote local construction materials & local construction practices with innovation so that skill of the local population can be upgraded and they can earn their livelihood by making safe, sustainable & affordable construction materials and housing. Local climate, social fabric and vulnerability of the society always is an important parameter in planning and designing of the

Fig. 6: Few innovative technologies used by HUDCO in Narela, Delhi: Present situation Year 2024

Fig. 7: Few innovative technologies used by HUDCO in Narela, Delhi: During Construction year 1997

physical infrastructure. Building center have been promoted all over the country by Hudco so that they can transfer knowledge from lab to the ground and hand hold the people.The previous work done by HUDCO involving few of these construction materials and construction techniques are as:

Various new and NBC compliant types of construction materials & construction technologies have been used in the construction of these public buildings in Year 1997, in a very aesthetic & pleasing way. Fly-Ash bricks, Rat-Trap bonded masonry, RCC Filler slabs, Brick Domes, Brick Arches, Ferro-Cement roofing channel, Funicular shells roofing, Frameless (E-Z) Doors/window frames, IPS flooring, Brick Jallies, Precast members, Ferro-Cement water tanks, etc., were used in the construction of these buildings, out of these building few were load bearing and few were RCC framed construction depending upon the requirements as per NBC of India. The cost of construction of these buildings with these interventions, was much less than the cost of construction of buildings with conventional construction materials and conventional techniques. However, the level of supervision required is much more in these innovative constructions. All of these buildings are doing good even after 20-25 years of construction and with minimal maintenance in Narela, Delhi. All of these buildings were designed in house completely by Structural Engineer, Dr Deepak Bansal and Architect Sri Rajiv Sood, under the guidance of Sri R K Safaya.

Hudco has demonstrated from pan India based post disaster rehabilitation works that built environment can be planned, designed & constructed using local resources & labour and this construction is disaster resilience as well as economic, energy efficient, sustainable and scalable. Hudco has done demonstrative construction works in almost all over India for almost all types of disasters using various local construction materials and construction technologies complying all the Codal /Bye-laws requirements in consultation with all stakeholders .

Note: The views expressed by the authors are personal and their organizations may or may not agree to the same.

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Visit of Government of Tanzania Delegation to BMTPC

UNDP in collaboration with the Ministry of Energy, Tanzania organized a session with BMTPC for an official delegation from the Government of Tanzania and its associated agencies.

The delegation was given insights about Government's initiatives towards innovative & alternate building materials, waste utilization in construction, new age construction systems. Also, on low cost building technologies, best practices on energy-efficient building materials/technologies, training, certification & standardisation and opportunities for knowledge exchange and potential collaborations.

Construction Monitoring:
A Paradigm Shift from Conventional to New Age Data-Driven Technology and Monitoring Systems

Prof. S. K. Singh [1] *Dhruvi Singh* [2]

Abstract

The construction industry is rapidly embracing digital transformation, with modern technologies such as the Internet of Things (IoT), Building Information Modelling (BIM), Artificial Intelligence (AI), drones, GPS, and cloud computing redefining infrastructure monitoring and management. Traditional inspection methods, often manual and time-consuming, are replaced by intelligent, automated, and data-driven approaches that ensure accuracy, efficiency, and long-term performance. This paper highlights innovative monitoring systems of the new age, focusing on embedded sensors in concrete structures, wireless data acquisition, and cloud-based decision-support platforms. These systems enable real-time insights into the structural health of buildings, bridges, and pavements, while supporting predictive maintenance and early failure detection. When integrated with AI-driven analytics, such data allows stakeholders to enhance safety, extend service life, and ensure sustainability. The convergence of cloud storage and machine learning provides seamless communication between on-site monitoring and remote platforms. This reduces reliance on manual site visits while enabling evidence-based decision-making through anomaly detection, visualisation, and mobile alerts. Globally, countries like Japan, the USA, and Germany are adopting fibre optic sensors, drone-assisted inspections, and BIM for asset management. In India, agencies promote innovative practices in the construction sector under national initiatives like Digital India, Smart Cities Mission, AGANII, Startup, Gati Shakti, etc. Looking ahead, intelligent monitoring can address challenges of quality control, delayed maintenance, and inadequate asset management. By aligning with SDGs, digital monitoring promises safer, more resilient, and climate-adaptive infrastructure for India's future

Keywords: BIM, Construction Monitoring, Digital Twin, Innovative Monitoring, IoT, AI.

1. Introduction

The engineering and construction industry is witnessing a paradigm shift from traditional manual monitoring of construction to technology-driven monitoring systems. The new age intelligent tools enhance efficiency, safety, and decision-making throughout the project lifecycle. Start-ups and technology firms are leading this change by introducing advanced hardware, software, and analytics platforms to address challenges of cost overruns, delays, and poor information flow faced by the construction sector. Digital tools, IoT devices, drones, wearables, and AI-based analytics now enable real-time construction monitoring, emphasising safety and quality, while supporting predictive decision-making and resource optimisation [1,2]. However, these technological interventions remain fragmented due to high costs, long payback periods, and low research and development investment. The construction sector spends less than 1% of its income on innova-

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tion compared to industries like aerospace or automotive. Small and medium enterprises face greater barriers, yet systematic digital adoption is increasingly critical for competitiveness [2].

Emerging technologies such as Wireless Sensor Networks (WSN), Fibre Optic Sensors (FOS), BIM, and RFID are expanding their applications in real-time data collection. Still, most implementations focus on maintenance and structural health monitoring (SHM) [2,3]. The vision ahead is the *"Construction Site of the Future",* a digital, context-aware ecosystem often described as the **digital skin of construction.** Integrating sensors, AI, and wireless computing promises greater safety, productivity, and sustainability. Yet, construction sites' dynamic, complex, and socially diverse nature remains a major barrier. Bridging the gap between technological readiness and industry adoption through systematic research and application-focused strategies will be key to realising truly smart, context-aware construction sites [3,4,5].

2. Monitoring of Construction

Monitoring ensures quality, safety, and durability in construction by providing accurate, timely decision-making. In construction, it provides activities of work, progress, early controls and confirms strength parameters before its actual usage. It also supports long-term durability (e.g., water and frost resistance) while reducing errors, delays, and maintenance, making it essential for sustainable and cost-effective construction [7, 8].

2.1 Conventional monitoring system

Conventional monitoring in construction has long depended on manual inspections, visual checks, data collection, periodic material testing etc. These methods face significant limitations in today's complex and fast-paced projects. Firstly, it is **subjective and error-prone**, relying heavily on human judgment, which can overlook data processing for the properties, micro-cracks, defects, or early signs of deterioration [6,7]. Secondly, it monitors **periodically rather than continuously,** missing dynamic variations in temperature, humidity, or stress that may compromise structural integrity. Thirdly, traditional inspections are **time- and labour-intensive,** slowing project timelines and inflating costs, especially in large or dispersed sites. Additionally, these methods provide **fragmented data** with minimal integration, limiting the use of advanced tools for assessing their health. Most critically, it remains **reactive; preventive** problems are often detected only after significant damage has occurred, driving up repair costs and undermining sustainability and cost effectiveness [7]. In summary, while traditional monitoring practices have served the industry for decades, their shortcomings in accuracy, efficiency, and predictive capability highlight the urgent need for advanced, technology-driven monitoring systems.

2.2 New age monitoring system

Advanced sensor-based monitoring systems, which continuously collect data on parameters like strain, temperature, maturity, humidity, and stress, with high accuracy around 90% while reducing inspection time. AI-driven systems take this a step further by gathering data automatically and analysing it using advanced algorithms that recognise patterns and predict potential issues in the construction. This approach increases accuracy to nearly 95% and cuts the required inspection time to only two hours. Beyond speed and precision, another critical advantage of modern methods is the shift from periodic to continuous monitoring.

The comparative charts below, Figs. 1 and 2 clearly demonstrate that modern monitoring technologies significantly outperform traditional inspection methods. Conventional inspections, which rely on manual checks, typically detect only about 65% of potential structural issues and require nearly eight hours per cycle, making the process slow and inefficient. While traditional inspections occur at scheduled intervals and may overlook early signs of distress, sensor-based and AI-driven solutions provide real-time monitoring, ensuring early detection of potential issues. This continuous oversight enhances safety, allows proactive maintenance, and reduces the likelihood of costly structural failures, highlighting a clear evolution from reactive to predictive and intelligent infrastructure monitoring [8,9].

2.3 Needs of digital transformation in construction

The construction productivity has remained flat, which is improved by digitalisation through automation and better planning [9]. The cost overrun is being checked effectively and efficiently through BIM and AI-based forecasting, which enhances financial control. The manual scheduling

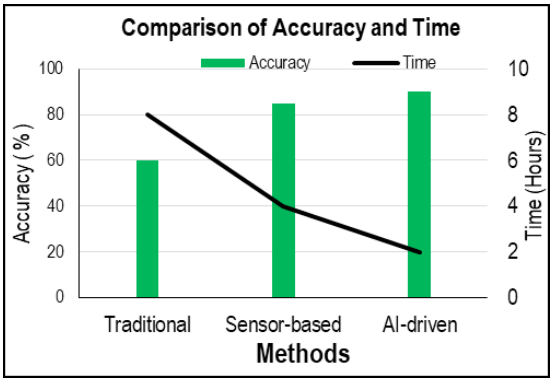

Fig. 1. Accuracy and time comparison

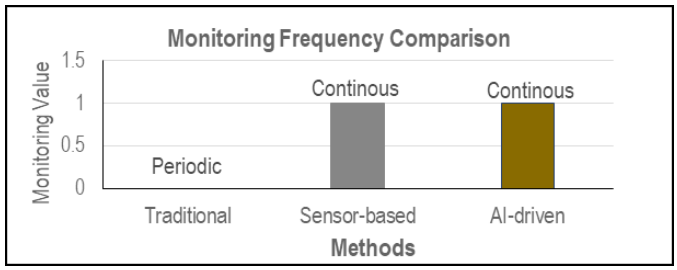

Fig 2: Periodic vs continuous monitoring

slows work, whereas 4D BIM and AI-driven planning reduce delays [9,10]. The system also works on worker Safety: Wearables, drones, and IoT improve hazard detection. Figs. 3 and 4 show Building Tomorrow with VR Technology and Smart Wearables, respectively. It reflects how construction is shifting towards smarter and safer practices. VR allows engineers and workers to enter a virtual project model, identify risks, and refine designs before construction begins.

The construction industry is transforming significantly by adopting advanced digital technologies that enhance monitoring, control, and decision-making across project lifecycles. Traditional monitoring methods are often manual, fragmented, and error-prone, making them inefficient for today's large-scale and complex projects [11,12].

3. Key Digital Technologies

Building Information Modelling (BIM) combines 3D models with time and cost data for tracking, risk analysis, and sensor/drone integration. Digital Twins enable simulation, fault detection, and better maintenance, while Wireless Sensor Networks (WSN) provide real-time structural and environmental data for predictive maintenance. RFID and IoT enhance material, equipment, and workforce management with safety compliance. Fibre Optic Sensing (FOS) ensures accurate strain and crack monitoring for long-term infrastructure health. UAVs with photogrammetry support site monitoring, 3D mapping, and safety inspections, complemented by AI and ML for risk prediction, anomaly detection, and decision support. Automation and robotics reduce errors through sensor-based inspections, GPS offers precise positioning and tracking, and GIS integrates spatial data for planning and environmental monitoring [12-18].

3.1 Building information modelling (BIM)

Building information modelling (BIM) is a digital process integrating a project's design, construction, and operation phases into a shared 3D model. It is a collaborative platform where stakeholders such as architects, engineers, and contractors can access, update, and exchange information in real time. BIM enables clash detection, cost estimation (5D BIM), time scheduling (4D BIM), and lifecycle management, improving accuracy and reducing delays, cost overruns, and rework. Beyond construction, BIM supports facility management and sustainability goals through energy modelling and material tracking.

Fig.3: Building tomorrow with VR technology

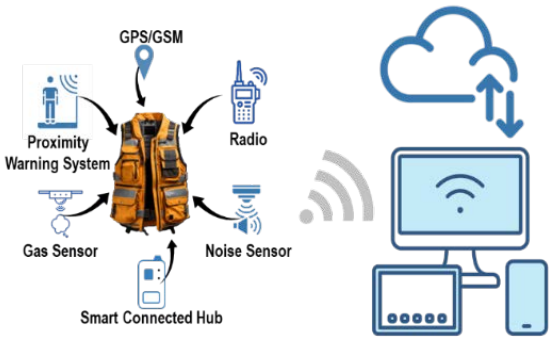

Fig.4: Smart wearables

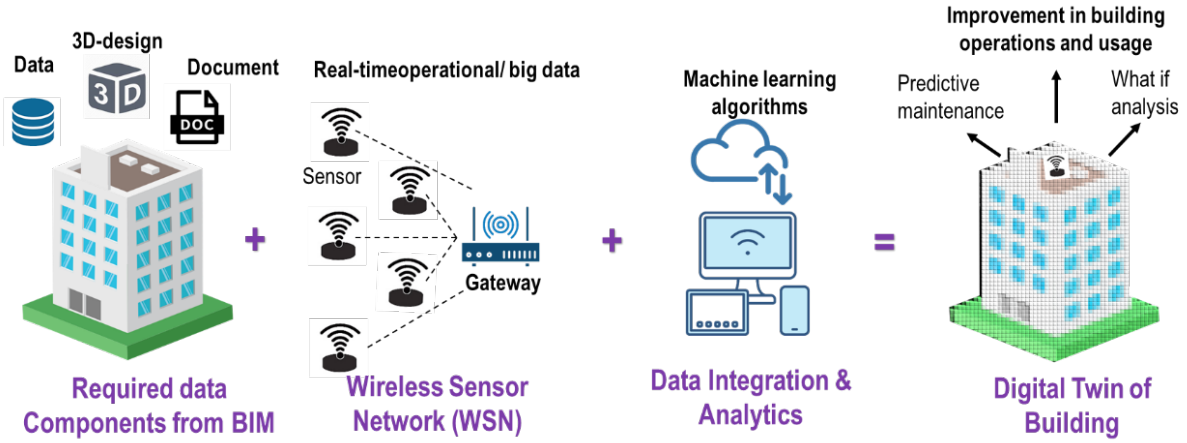

Fig.5: Digital Twin of Buildings

Its adoption enhances collaboration, transparency, and efficiency, making it a cornerstone of digital transformation in the construction industry [19–20]. In **Fig. 5, the Digital Twin of Buildings** illustrates the integration of virtual and physical worlds, creating real-time replicas updated with sensor and IoT data. **This** demonstrates the integration of virtual and physical worlds in construction.

Benefits of BIM

- Cloud-based BIM platforms allow real-time coordination between stakeholders.
- 4D/5D BIM reduces scheduling delays and cost overruns [24].
- Clash detection and digital simulation minimise design errors and quality control issues.
- Energy modelling and material tracking help meet environmental goals.
- Provides valuable data for operations, maintenance, and life cycle management.

Limitations of BIM

- Requires high initial investment due to costly software, hardware, and training.
- Demands learning curve, skilled professionals, and a shift in traditional workflows.
- Data management challenges due to handling large, complex BIM files.
- Interoperability issues-Different BIM software may have compatibility problems.
- Adoptability challenge- Small firms and contractors may hesitate to adopt BIM practices.

Thus, while BIM offers transformative potential for the construction industry, its implementation challenges highlight the need for strategic investment, training, and standardisation.

3.2 Digital Twin for Construction Monitoring

Monitoring the progress of construction projects is critical for ensuring cost efficiency, timely delivery, and quality assurance. Traditional monitoring methods rely on manual data entry and visual inspections and are often time-consuming and error-prone. Building Information Modelling (BIM) and Digital Twin (DT) technologies are increasingly being adopted to overcome these limitations. BIM models serve as digital representations of the design phase (as-designed) and can be compared with field-based updates (as-built models) to detect deviations. While BIM provides a structured and information-rich model, it is essentially static. In contrast, Digital Twins (DTs) extend BIM by integrating real-time sensor data, historical records, and simulation capabilities, creating a dynamic and interactive replica of the physical asset.

A recent case study demonstrated the creation of a DT to monitor the construction of a wind farm. BIM models from the design phase were compared with simulated as-built models to capture deviations in road alignments, slopes, and turbine placements. Using Unreal Engine, the researchers developed a game-like interface that allowed stakeholders to visualise construction progress over time, fly through the project site, and interactively compare as-designed and as-built models. A non-relational MongoDB database was used to store and analyse deviations, enabling flexible data management [20,21].In **Fig. 6,** represents how the construction industry is evolving towards a more data-driven and intelligent approach. Digital twin technology goes beyond simple 3D models by creating a dynamic, real-time replica of the physical structure, enriched with sensor and IoT data. This allows engineers to simulate

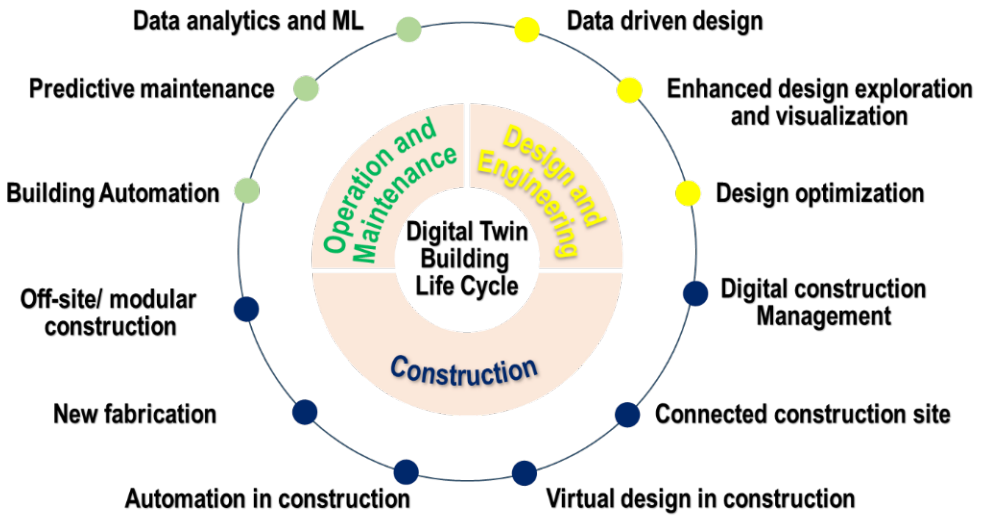

Fig. 6: Re-imagining Construction with Digital Twin Technology

different scenarios, optimise resource use, and predict potential failures before they occur. By re-imagining construction through digital twins, projects can achieve higher efficiency, sustainability, and safety while reducing delays and costs.

Digital Twins (DTs) enhance construction monitoring by providing interactive visual tools, real-time detection of design deviations, predictive simulations, and accessible interfaces for non-experts. Challenges remain in automating as-built model generation and continuous updates, but future solutions like runtime data integration plugins are expected to overcome these limitations.

3.3 Wireless Sensor Networks (WSNs)

Wireless Sensor Networks (WSNs) have emerged as an advanced alternative to conventional wired monitoring systems, offering scalable and real-time solutions for Structural Health Monitoring (SHM). A typical WSN comprises spatially distributed sensor nodes with sensing units, processors, wireless transceivers, and power sources. These nodes measure key parameters such as strain, vibration, acceleration, temperature, humidity, and load, transmitting data wirelessly to a base station or cloud platform for processing [20,21].

The architecture of WSNs generally includes three layers: sensor nodes embedded within or attached to structures, a wireless communication network (e.g., ZigBee, LoRa, Wi-Fi, Bluetooth Low Energy), and a gateway that interfaces with centralised monitoring systems. These networks, coupled with Artificial Intelligence (AI) and Machine Learning (ML), enable automated anomaly detection, predictive maintenance, and infrastructure lifecycle management.

Applications of WSNs span bridges, high-rise buildings, dams, tunnels, and heritage structures. For example, bridge strain and vibration sensors provide early fatigue warnings, while tall buildings' accelerometers capture responses to wind and seismic loads. In underground or water-retaining structures, WSNs monitor seepage, displacement, and microclimate variations, critical to long-term durability.

Key advantages of WSNs include simplified installation, reduced cabling costs, scalability, and the ability to function in inaccessible or hazardous environments. However, challenges such as limited power supply, susceptibility to signal interference from concrete and steel, data security, and sensor durability in harsh conditions remain [20,21].

Future research is advancing toward self-powered sensor nodes using energy harvesting (e.g., solar, vibration-based), IoT and cloud-based analytics integration, and AI-driven predictive models. These developments are expected to establish WSNs as a cornerstone technology for monitoring resilient, safe, and sustainable infrastructure [20,21,22]. **Fig.7** demonstrates how sensor-equipped devices enable continuous monitoring of construction sites. Data on structural performance, environmental conditions, and worker safety is collected in real time and transmitted through IoT networks for remote access. This system sup-

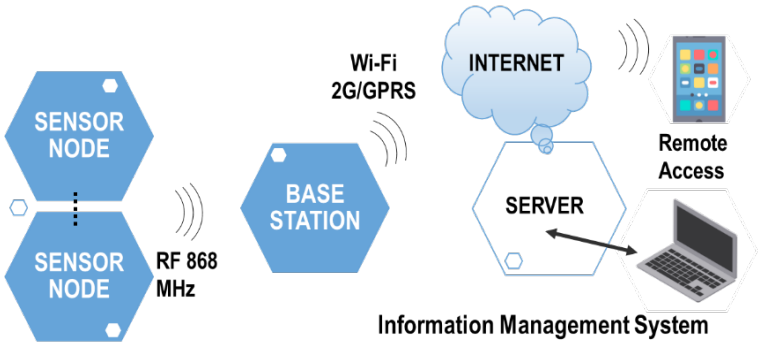

Fig.7: IoT-based data collection and remote access system

ports faster decision-making, predictive maintenance, and improved project management by providing stakeholders with accurate insights anytime, anywhere.

3.4 IoT for Construction Monitoring

A significant trend within the current digital revolution is that the cyber and physical environments are becoming more and more interconnected at different levels due the diffusion of IoT, the infrastructure of devices and objects that are connected to the internet and can gather and transmit data on their particular state which can be collected for monitoring, control, statistical analysis and decision support [23-24]. Integrating Internet of Things (IoT) devices in construction has revolutionised monitoring by enabling real-time data collection from structures, machinery, and the environment. IoT-based solutions include wearable sensors for tracking worker safety, environmental sensors for temperature, humidity, and dust levels, and structural sensors such as strain gauges, vibration detectors, and fibre optic systems for detecting stress, cracks, and displacements. In addition, drones and RFID technologies support material management and progress tracking, offering continuous data streams that enhance safety, quality, and productivity on-site [25]. While IoT provides the data, Artificial Intelligence (AI) transforms it into actionable insights. AI techniques such as predictive maintenance models help identify equipment failures in advance, while computer vision algorithms enable automated defect detection and quality control. Furthermore, AI-driven project planning and resource allocation reduce delays, and risk prediction models integrate IoT data to identify safety hazards before they escalate. By combining IoT sensing capabilities with AI-driven analytics, construction projects benefit from improved efficiency, reduced risks, and enhanced decision-making [26,27]. In **Fig. 8,** highlights how connected sensors track key parameters like load, stress, temperature, and humidity in real time, ensuring early detection of risks and enhancing site safety. Figure 9 shows how embedded sensors in reinforcement bars help track stress, strain, and corrosion levels. This real-time monitoring ensures structural durability and supports timely maintenance decisions.

In reinforced concrete construction, computer vision and AI detect binding wires and predict rebar placement to ensure reinforcement quality. CNN-based deep learning models analyse site images or 3D scans to verify spacing, alignment, and quantity. This automation reduces manual errors, ensures design compliance, prevents rework, and enhances safety and efficiency in construction monitoring [28].

3.5 Fibre Optic Sensors

Fibre optic sensors (FOS) are widely used in structural health monitoring due to their **high sen-**

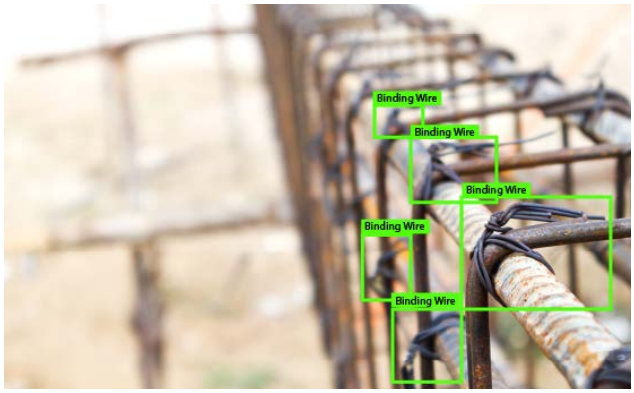

Fig.8: IoT in action: real-time monitoring

Fig.9: Monitoring rebar with IoT

sitivity, durability, and immunity to electromagnetic interference. They work on transmitting light signals through optical fibres, where strain, temperature, or vibration changes alter the light properties (intensity, phase, wavelength). Fibre Bragg Grating (FBG) sensors are the most common type, which can simultaneously measure strain, displacement, cracks, and temperature, making them highly suitable for **long-term monitoring of bridges, tunnels, dams, and high-rise buildings**. Unlike traditional electrical sensors, FOS are lightweight, corrosion-resistant, and can be **embedded directly into concrete** during casting. By enabling **real-time, distributed measurements**, fibre optic sensors improve **early defect detection, predictive maintenance, and overall infrastructure safety** [29,30].

3.6 UAVs and Photogrammetry

In recent years, Unmanned Aerial Vehicles (UAVs), commonly called drones, combined with photogrammetry techniques, have emerged as powerful tools for construction monitoring. UAVs enable rapid and frequent data acquisition from construction sites, while photogrammetry converts aerial imagery into accurate 2D maps and 3D models. This integration supports digitising and automating construction progress monitoring [31].

Progress tracking: UAVs capture high-resolution aerial images of construction sites at regular intervals. Photogrammetric processing transforms these images into as-built 3D models, which can then be compared with BIM (as-designed models) to identify deviations in geometry, alignment, or material placement [32,33]

Topographic mapping and earthworks: UAV-based photogrammetry produces Digital Terrain Models (DTMs) and Digital Surface Models (DSMs) that allow precise monitoring of earthmoving activities, excavation volumes, and terrain adjustments [34-36].

Quality control and safety: Drones provide real-time aerial surveillance, enabling project managers to assess safety compliance, detect hazardous conditions, and ensure quality assurance without physical site inspections [37,38].

Integration with Digital Twins and BIM: Photogrammetry-generated point clouds can be integrated into BIM platforms or Digital Twin environments, allowing side-by-side comparison between planned and actual progress [39].

The use of UAVs in construction offers several advantages, including non-intrusive and rapid data collection, cost-effectiveness compared to manual surveying, high spatial accuracy suitable for large sites, and the ability for frequent, automated monitoring. However, limitations include dependence on weather conditions, the need for skilled operators and data processing expertise, and regulatory restrictions in urban or sensitive areas.

3.7 AI and ML

Artificial intelligence (AI) refers to computer systems that mimic human cognitive processes, enabling intelligent decision-making, pattern recognition, and predictive analysis, whereas Machine learning (ML), a subset of AI, allows systems to learn from data over time without explicit programming, improving accuracy in interpreting information and predicting outcomes. In the construction industry, AI and ML are applied across all stages of the building life cycle, design, construction, operation, and maintenance—for monitoring, optimisation, and decision support.

AI and ML enhance construction monitoring across all project phases. During the design phase, surrogate models and Generative Design enable rapid evaluation of alternatives and detect errors or conflicts in MEP plans, improving accuracy and approval times [39]. In construction, AI-powered robots, autonomous vehicles, and drones monitor activities, resources, schedules, and safety, while predicting delays, costs, and waste; **Figs. 11 and 11** demonstrate how automation improves speed, accuracy, and efficiency, boosting labour productivity and reducing costs. In operation and maintenance, AI and IoT sensors optimise building systems, predict occupant behaviour and energy demand, enable adaptive control, and support predictive maintenance for structural health, extending asset life and reducing downtime [39].

3.8 Automation and robotics in construction monitoring

Automation and robotics transform construction monitoring, enabling safer, faster, and more accurate project execution. Drones and ground robots capture real-time visual and structural data, reducing reliance on error-prone manual inspections. Robotic systems handle materials precisely, while IoT and AI provide predictive insights on structural fatigue, safety risks, and schedule delays. These technologies enhance safety, productivity, and decision-making with accurate, real-time data [40–43].

Fig.10: Robotic welding for smarter construction

Fig.11: Robotics in construction

3.9 GPS and GIS in construction monitoring

GPS provides real-time location data of construction assets, enabling precise tracking of machinery, vehicles, and personnel. It helps monitor equipment utilisation, manage material deliveries, ensure worker safety in hazardous zones, and track site progress efficiently [44,45]. GIS integrates spatial data with project information to create interactive site maps. It visualises terrain, drainage, utilities, and temporary structures, monitors environmental conditions (weather, soil, and water flow), and overlays BIM models for design comparison and clash detection. GIS also supports analytics for productivity, risk, and resource allocation [45].

By combining GPS with GIS, construction managers gain real-time situational awareness. GPS feeds location data into GIS, integrating it with site maps, BIM, and environmental layers. This enables live dashboards showing equipment positions, worker locations, progress against schedules, and hazard alerts. The system supports predictive decision-making, efficient resource allocation, and remote supervision [44,45]. The benefits of digital monitoring in construction include real-time visualisation of site activities, early hazard detection for improved worker safety, and efficient resource allocation with accurate progress tracking. When integrated with BIM, it also enables design verification and clash detection. Overall, these capabilities support data-driven decision-making and help reduce project delays.

Geotagged data in construction offers several advantages, starting with precise progress tracking through photos, videos, and sensor data tagged to specific locations, enabling managers to identify completed or pending tasks. Its integration with GIS and BIM allows overlays on site maps or 3D models for comparing planned versus actual progress. Additionally, it supports accurate documentation and auditing, ensuring reliable records for quality control and regulatory compliance. Geotagged sensor readings, such as temperature, strain, or moisture, also help detect site-specific issues like concrete curing problems or structural anomalies.

Geolocation technologies in construction enhance safety and efficiency by sending real-time alerts when workers or supervisors enter hazardous zones. They also support task and resource management by directing personnel and machinery to exact work locations. With real-time oversight, supervisors can track worker and equipment movement and take immediate corrective actions when deviations occur. Additionally, these systems improve efficiency by automatically guiding resources to priority areas, ensuring timely project execution. Geotagging and geotargeting are essential digital monitoring tools in modern construction, integrated with GIS, GPS, IoT, and BIM. Geotagging attaches location-specific data to photos and sensor readings for progress tracking and issue detection, while geo-targeting provides real-time alerts, guides workers, and ensures safety. They streamline data collection, resource management, and decision-making, enhancing site productivity and safety [46].

4. Conclusions

Construction significantly shifts by combining BIM, IoT, AI, and robotics with construction practice. These tools improve monitoring, efficiency, and safety, while reducing costs and delays. Challenges remain in investment, skills, and collaboration, but supportive policies and digital adoption will accelerate change. Ultimately, Construction

promises a future of efficient, resilient, and sustainable building delivery. The future of Construction lies in the deeper integration of digital tools. Digital twins will become standard, linking real-time data with virtual models for continuous optimisation. AI, analytics, and 5G-enabled IoT will enhance predictive planning, robotics, and automation. Circular economy practices will reduce waste by tracking and reusing materials. With increasing BIM mandates and green-building requirements, the sector is moving toward faster, smarter, and more sustainable practices worldwide.

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National Conference-cum-Expo on Innovative Building Materials & Construction Technologies

To take stock of the recent developments, BMTPC as part of its endeavor to identify and promote alternate, innovative, environment friendly and disaster resistant building materials and construction technologies, organized the National Conference-cum-Expo on Innovative Building Materials & Construction Technologies on March 19-20, 2025 at New Delhi so as to bring all stakeholders on one platform to share their knowledge and experience.

The 2-days National Conference-cum-Expo was inaugurated by Shri Kuldip Narayan, Joint Secretary & Mission Director (HFA), Ministry of Housing & Urban Affairs, Government of India in the presence of Shri Sanjay Kulshrestha, Chairman & Managing Director, Housing & Urban Development Corporation (HUDCO); Dr. V.K.Paul, Director, School of Planning and Architecture New Delhi; Prof. (Dr.) Anil Kashyap, Chancellor, NICMAR University & Director General, NICMAR; Shri Sanjay Seth, Senior Director, TERI and Vice President & CEO, GRIHA Council; Maj. Gen. (Dr.) Ashok Kumar VSM (Retd.) and Dr. Shailesh Kr. Agrawal, Executive Director, BMTPC.

To coincide with the National Conference, an Expo was also organized wherein 24 agencies/ companies displayed their innovative products, technologies and systems. Technology Providers also made their technical presentations showcasing their products/ systems. About 350 delegates participated in the Conference, which included representatives from Urban Local Bodies/ State Govts, faculty & students of technical/ architectural institutions, Executives from various PSUs, Practicing Architects/ Engineers from Private agencies etc. An Exhibitor's Catalogue was also released during the event.

Wetlands – The Silent Managers of Urban Crises



Shradha Deshpande [1] *Kumar Abhinay* [2] *Dr. Mahua Mukherjee* [3]

Wetland Conservation: Revival of the Kidneys of Our Landscape

India has observed infrastructural growth and urbanization at a pace unprecedented in history, with the rapid conversion of blue-green landscapes into grey settlements. It is further estimated that 40% of India's population may live in urban locales by 2030, deriving a hefty ecological cost. This highlights the alarming trajectory of development that overlooks essential natural systems to satiate the anthropogenic demand *(Abhinay et al., 2024; Mukherjee et al., 2023)*. It is astonishing to observe that one such natural system, proudly referred to as 'kidneys of our landscape', is the wetlands. They play a vital role in filtering pollutants, regulating hydrology, and sustaining biodiversity. Once interwoven into the hydrological and cultural fabric of Indian cities, the wetlands have been systematically polluted, diminished, or repurposed for real estate and city expansion projects *(Poudel et al., 2024; Ahmad et al., 2024)*.

In the three decades alone, India has lost 30–35% of its wetlands, and an inexplicable 50–70% from urban areas. These natural buffers protect against the shocks of extreme flooding and intense heatwaves *(Dhiman et al., 2019; Baghel, 2016)*, and their steady disappearance means that once occasional disasters are becoming chronic features of urban life.

The preservation of wetlands predominantly relies on engineered restoration solutions such as stormwater drains, flood walls, etc., consuming vast amounts of financial and natural resources. However, over time, the limitations of human engineering reveal incongruity. Much like dialysis machines that can never truly replace natural kidneys, over-engineered solutions cannot substitute for the multifunctionality of wetlands *(Kumar et al., 2021; Kadaverugu et al., 2021)*.The crisis of wetland loss within the broader challenges of urbanization and climate resilience in India underscores that their holistic conservation is not a luxury but an imperative *(Singh et al., 2013; Hettiarachchi & McAlpine, 2014)*.

Beyond Numbers: The Invisible Loss of Wetlands

The attribute that has long been the subject of investigation to grasp this intricate system is its intermediate status between terrestrial and aquatic. India consists mostly of diminutive wetlands; 90% of documented wetlands measure less than 0.1 hectare in area. Whereas the Ramsar Convention uses a 40-type categorization system, the Space Applications Centre (ISRO) recognizes 24 categories in national reporting *(ISRO-SAC, 2024)*.

Recent research brings to the fore that between 1700 and 2020, India saw a 39% shrinkage of wetlands from an estimated 61.3 million hectares (Mha) to 37.2 Mha. More recent evaluations utilizing the ISRO National Wetland Atlas (2024) indicate an even steeper

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contraction with mapped wetlands confined to 16.89 Mha *(ISRO-SAC, 2024; Government of India, 2023)*. Against the historical benchmark, this implies a cumulative loss of about 72% of India's wetlands over the last three centuries. But the most vulnerable of these environments, the small wetlands, are still falling through the cracks of definition and assessment *(Yadav et al., 2025).*

While inventories are the mirrors in which we gauge our ecological well-being, India's wetland mirror is still misty, showing us only glimpses of reality. Table 1 includes records of type-classified wetland loss but emphasizes the alarming categories *(EnviStats India, 2020).*

In today's world, the growing frequency of disasters fuelled by rapid climate change highlights the urgent need to rethink the development paths society has followed. Nowhere is this urgency more visible than in India, where wetlands have shrunk by more than two-thirds of their historical spread *(Mukherjee et al., 2023; Ahmad et al., 2024).* Wetlands are multifunctional ecosystems, best known for flood control and water regulation, but they also play key roles in thermal regulation of cities, biodiversity enrichment, and offering recreation.

As India's metropolitan regions expand, the loss of wetlands has directly heightened the risk of urban flooding, a reality most clearly seen in Bangalore, Mumbai, Delhi, and Chennai *(Abhinay et al., 2024; Baghel, 2016; Zope et al., 2015).*

Metropolis and its attitude: the slate of urban crisis

A comparison of pre- and post-monsoon wetland areas shows a 48.26% expansion in area, which highlights the significant contribution of wetlands towards water storage and hydrological regulation. As inferred from table 1, the trends of Bangalore, Mumbai, Delhi, and Chennai exhibit the same pattern: widespread wetland loss due to unplanned urbanization, followed by increasing flood catastrophes *(Baghel, 2016).*

Bangalore has witnessed one of the sharpest declines in water bodies among all Indian cities. Temporal assessments show a drastic drop in the number of lakes from 51 in 1973 to only 17 in 2007, together with a 58% loss of lake area. Contraction has decreased the city's natural ability to soak in monsoon rains, the immediate cause of frequent urban flooding *(Kadaverugu et al., 2021).*

In Mumbai, loss of floodplain and wetland has been just as dramatic. The Mithi River floodplain and associated marshes have been extensively reclaimed since the 1970s, causing almost 40% of natural wetlands to vanish by the early 2000s. The deadly 2005 floods that killed more than 500 people and brought the city to a standstill were blamed not only on heavy rainfall but also on the loss of drainage channels and wetland buffers *(Zope et al., 2015; Baghel, 2016).*

Delhi exhibits a similar but no less ominous trend. The Yamuna floodplain, a traditional sponge for seasonal flooding, has seen encroachment of well over 60% of its low-lying retention areas and wetlands since the 1980s. Urbanization, infrastructure expansion, and industrial development have reduced retention storage, exacerbating flood risks *(Singh et al., 2013; Yadav et al., 2025).*

Chennai accounts for one of the most dramatic instances of wetland loss in urban areas. Traditionally, the city had approximately 150 water bodies, but this was reduced to 27 in the 2010s, which amounted to a loss of over 80% in terms of numbers and over 50% in terms of wetland coverage. This contraction drastically lowered the resilience of the city, and the catastrophic 2015 floods were the immediate result of breaching drainage and storage capacity *(Devi et al., 2020; Baghel, 2016).*

Together, these urban paths highlight a sobering truth: wetland erosion not only magnifies the intensity and frequency of urban flooding but also disassembles a vital layer of ecological resilience. But flooding is not the sole aspect of this crisis. When wetlands disappear, cities lose their natural ability to moderate temperature, exacerbating urban heat stress and multiplying the challenges of climate adaptation. *(Dhiman et al., 2019).*

Heat-stress

Yet another unseen but no less dangerous aspect of urban risk manifests in the form of heat stress. Projections of climate suggest that the mean maximum temperature in India would increase by 1.9-2.1°C by the mid-21st century, with even more precipitous increases during pre-monsoon summer seasons *(Mukherjee et al., 2023).* The *Managing Climate Risks in Wetlands* guide highlights that increased water temperatures and contracted wetland cover impair water quality, worsen pollution, and exacerbate the incidence of waterborne diseases *(ICEM, 2023;*

Ahmad et al., 2024). These changes are not singular ecological issues; they come together to affect human well-being by stretching urban healthcare systems and exacerbating socio-economic disparities.

In the Kolkata Metropolitan Region, wetland zones were found to be 2-4°C cooler than adjacent built-up areas, reducing urban heat island intensity by up to 35% and significantly lowering surface heat stress in densely populated wards *(Singh et al., 2013).* In Nawabganj, Uttar Pradesh, wetland buffers improved the Human Comfort Index by 12-18% and reduced peak summer air temperatures by 1.5-2.2°C, directly translating into fewer heat stress days for nearby populations *(Yadav et al., 2025).* Delhi, on the other hand, shows the effects of wetland loss: almost 60% of Yamuna floodplain wetlands have been encroached since the 1980s, accompanying a 1.5°C increase in mean summer surface temperature and a doubling of extreme heat days over 40°C *(Yadav et al., 2025).* In Chennai alone, over 80% of wetlands have lost their existence, and pre-monsoon land surface temperatures have increased by almost 2°C, accompanied by increased hospitalization for dehydration, heatstroke, and vector-borne disease from 2019 to 2023 *(Nithila Devi et al., 2020; Baghel, 2016).* Comparative studies of megacities in the Global South also substantiate this trend, illustrating that urban peri-urban wetland loss raises land surface temperature by 3-5°C and aggravates the heat stress index by 20-25%, with unequal effects on poor urban communities *(Poudel et al., 2024; Mukherjee et al., 2023).*

Thus, in this context, wetlands appear not only as environmental buffers but as important public health infrastructure. Their conservation and restoration are a nature-based solution to climate resilience and health security alike, providing cooling, clean water, and disease regulation all at once *(ICEM, 2023; Adhya & Banerjee, 2022).* The public health impacts of their loss are already evident in India's urban areas, from the heat-related health crises in Chennai to the worsening heatwaves in Delhi, highlighting that protection of wetlands is part of protecting urban populations in a changing climate. Expanding this acknowledgment, there is a critical window to rethink wetlands not as leftover spaces but as frontline nature-based solutions, living systems to ground adaptive and resilient cities of the future *(Poudel et al., 2024).*

Table 1: Category-wise changes in wetland area (2022-to-2024)

Wetland Category	Change (%)	Inference
Lakes	−37	Significant decline
Riverine wetlands	−34	**Sharp reduction**
Natural waterlogged	−21	Shrinking extent
Human-made waterlogged	−44	**Almost halved**
Salt pans (inland)	−33	**Inland salt pans declining**
Oxbows	−4	Minor decrease
High-altitude wetlands	−2	Slight decline
Sand / Beaches	−25	**Coastal sand/beach areas lost**
Lagoons	−6	Small decline
Intertidal wetlands	−35	**Major loss of mudflats/intertidal zones**
Saltpans (coastal)	−13	Moderate decline
Coral reefs	−2	Small decline

Wetlands: the multifunctional 'Natural Infrastructure'

Wetlands play a multifunctional role as "saviours" of water management, providing essential services like flood control, water filtration, drought resistance, and climate regulation. Spanning approximately 6% of the Earth's surface, wetlands deliver water-related ecosystem services worth approximately US$47 trillion a year, almost 43% of the entire value of global ecosystem services. As natural sponges, wetlands are capable of retaining 30–90% of floodwater peak *(Abhinay et al., 2024; Mukherjee et al., 2023)*. Urban wetlands minimize peak flows by 20-50%, whereas restored floodplains in Europe and Asia reduce downstream floods by as much as 50%. Case studies from Indian cities also demonstrate that wetlands act as frontline buffers against flooding *(Zope et al., 2015; Devi et al., 2020)*.

Wetlands also purify water, eliminating 20-60% of nitrogen and as much as 70% of phosphorus. Wetlands of small size eliminate E. coli by 40-60%, whereas municipal treatment wetlands remove 70-90% of suspended solids and BOD. *(Devi et al., 2020)*. In addition, they replenish groundwater, rais-

ing rates by 15–25%, and enhance soil water in semi-arid areas by 20–30%, supporting water supplies for millions, particularly in India's Ganga and Brahmaputra basins.

Climate control is a function of prime importance. Wetland evapotranspiration cools local climates by 2-5°C, while peatlands hold approximately 550 gigatons of carbon *(ICEM, 2023; Yadav et al., 2025)*. In India, urban wetlands enhance human comfort by 12–18% through heatwave mitigation. With identification by more than 170 Ramsar signatory nations and incorporation into 48 Nationally Determined Contributions (NDCs), wetlands emerge as natural buffers against climate extremes and bases for socio-economic resilience.

Outside ecology, wetlands are the foundation of economic and social structures. They support inland aquaculture and fisheries, offering protein security for millions alongside billions of dollars in annual income. For example, in 2021, pen farming in the "Duma" wetland of the lower Gangetic floodplain (West Bengal) yielded '15' tons of commercial fish worth approximately ₹30 lakhs in one season, in addition to small indigenous fish supporting local diets *(Adhya & Banerjee, 2022)*. Floodplain wetlands in India generally enhance inland fish yields significantly, supporting livelihoods and rural economies. Wetlands also sustain aquaculture, paddy cultivation, and grazing via a consistent source of water, while allowing for small-scale reeds, medicinal plants, and fodder harvesting. Ecotourism and birdwatching along Ramsar wetlands such as Chilika Lake and Keoladeo National Park generate significant employment *(Government of India, 2023; Ministry of Environment, 2024)*. Worldwide, wetlands sustain 660 million people directly via fishing, agriculture, and related industries, making them both economic lifelines and ecological buffers.

Conserve - Retrofit - Refurbish

Wetlands are naturally multifunctional, with important services including flood protection, water filtration, groundwater recharging, and climate moderation. Excessive reliance on built "grey" solutions such as dams, levees, and artificial treatment facilities can temporarily control water hazards but cannot substitute for the combined ecological services of wetlands *(Mukherjee et al., 2023; Kumar et al., 2021)*; overly engineered systems are like dialysis machines, keeping alive but incapable of completely substituting natural kidney functions. Thus, conservation initiatives in India and worldwide must prioritize retrofitting and refurbishing existing wetlands through nature-based solutions (NBS), blue-green infrastructure (BGI), and hybrid solutions rather than creating entirely new, resource-intensive systems *(Poudel et al., 2024)*.

A key step is the scientific demarcation of wetlands using remote sensing, GIS, and ground-truthing to accurately establish boundaries, track temporal changes, and set priorities for restoration *(Abhinay et al., 2024; Yadav et al., 2025)*. Such evidence-based mapping ensures interventions are targeted, ecological well-being is monitored, and conservation action can be evaluated systematically *(Poudel et al., 2024)*.

Nature-based solutions restore hydrological connectivity and native vegetation, enabling wetlands to regulate seasonal flows and support biodiversity. In floodplains like the Ganga and Brahmaputra, rejuvenation efforts have shown that combining ecological restoration with adaptive engineering measures sustains both ecosystem function and community livelihoods *(Poudel et al., 2024; Adhya & Banerjee, 2022)*. These initiatives exemplify how hybrid grey-blue-green strategies—integrating sluices, sediment traps, modular retention basins, and overflow channels with native vegetation buffers—can provide reliable flood control and water treatment without undermining ecological integrity *(Kumar et al., 2021; Dhiman et al., 2019)*.

Urban retrofitting also demonstrates the multifunctionality of wetlands when integrated into blue-green infrastructure. Projects in Chennai, Pune, and Hyderabad reveal how stormwater ponds, constructed wetland modules, bioswales, rain gardens, retention ponds, and vegetated swales reduce flood risk, moderate heat islands, and create recreational spaces *(Kadaverugu et al., 2021; Dhiman et al., 2019)*.

By focusing on retrofitting, modular integration, and evidence-based interventions, wetlands can be sustained in their multifunctionality, strengthening urban and rural resilience while providing critical ecosystem services at lower financial and environmental costs *(Poudel et al., 2024; Mukherjee et al., 2023)*.

The Policy Lens

Policy designs and implementation strategies are critical to promoting wetland conservation and incorporating nature-based solutions (NBS) and blue-green infrastructure (BGI) in urban planning *(Poudel et al., 2024)*. India has the *Wetlands (Conservation and Management) Rules, 2017* as a backbone of such efforts, which equip State Wetland Authorities (SWAs) to identify, delineate, and notify wetlands while clearly curtailing encroachment, reclamation, or random construction *(Mukherjee et al., 2023)*. The Ministry of Environment, Forest, and Climate Change (MoEFCC) has formulated detailed guidelines to guide the implementation of such rules, such as the creation of Integrated Management Plans (IMPs) for monitoring ecological character *(Poudel et al., 2024)*.

The Supreme Court of India (2024–25) has recently instructed states to speed up wetland demarcation, underscoring their ecological significance. The decision has, however, generated controversy among urban planners, developers, and conservationists, indicative of the conflict between short-term economic profit and long-term ecological sustainability *(Poudel et al., 2024; Abhinay et al., 2024)*. Community participation and public awareness continue to be essential to successful wetland management, with programs such as citizen monitoring, education campaigns, and "Wetland Mitras" programs empowering local communities *(Mukherjee et al., 2023; Poudel et al., 2024)*.

Financial frameworks also enable conservation, incentivizing eco-restoration and wetland-focused urban development to catalyse retrofitting of existing wetlands and implementation of BGI *(Poudel et al., 2024)*. Initiatives such as the National Wetlands Conservation Programme (NWCP) offer policy guidance, high-intensity conservation actions, and facilitate community participation *(Ahmad et al., 2024)*. The designation of 91 Wetlands of International Importance by India highlights the nation's commitment to international conservation norms *(Poudel et al., 2024)*. But translating that on ground is a major crisis, as enforcement gaps remain between central directives and state-level execution *(Ahmad et al., 2024)*.

Robust monitoring and adaptive management, embedded in IMPs, have yielded positive outcomes, exemplified by Chennai's Adyar Eco Park, where restoration enabled successful Painted Stork breeding *(Nithila Devi et al., 2020)*. Similarly, Udaipur's recognition as a Ramsar Wetland City illustrates how integrating traditional water bodies with modern urban planning fosters sustainable urban resilience *(Hettiarachchi & McAlpine, 2014)*. Through the integration of regulation enforcement, financial incentives, community engagement, and hybrid infrastructure strategies, policy interventions can conserve wetlands effectively while keeping their multifunctional ecological services for water management, biodiversity, and climate resilience *(Poudel et al., 2024; Mukherjee et al., 2023)*.

The way forward

Urban wetlands represent both neglect and need but present low-cost, high-benefit options for dealing with issues like heat stress, water scarcity, and flood management in Indian cities.

Good conservation demands scientifically demarcated wetlands utilizing remote sensing, GIS, and ground-truthing so that boundaries are properly identified and ecological well-being is correctly assessed *(Abhinay et al., 2024; Yadav et al., 2025)*. Urban planning of wetlands as part of climate action plans and smart city programs guarantees that they actively serve stormwater management, temperature control, and biodiversity enhancement *(Poudel et al., 2024; Mukherjee et al., 2023; Kumar et al., 2021)*.Restoration should be given higher priority than solely engineered solutions, with recognition that restored wetlands offer multifunctional services that grey infrastructure cannot match *(Poudel et al., 2024; Dhiman et al., 2019)*. Evidence from South Asia indicates that retrofitted and restored wetlands significantly improve resilience by combining ecological and infrastructural benefits *(Mukherjee et al., 2023)*. Community stewardship is critical, with citizens participating in monitoring, education, and co-management to promote long-term protection and consciousness *(Poudel et al., 2024; Hettiarachchi & McAlpine, 2014)*. Citizen-science initiatives such as India's *Wetland Mitras* have shown that participatory governance strengthens ecological outcomes and ensures accountability in local contexts *(Abhinay et al., 2024; Adhya & Banerjee, 2022)*.Protective legislation needs to be strengthened through complete enforcement of the Supreme Court's order on demarcation of wetlands, complemented by accountability measures for state governments to avoid encroachment and ensure sustainable management *(Mukher-*

jee et al., 2023; Ahmad et al., 2024; Poudel et al., 2024). Stronger integration of wetland conservation into urban development policies is also essential, particularly as Indian cities expand into peri-urban landscapes that traditionally host critical floodplains (Ahmad et al., 2024; Kumar et al., 2021).

Policymakers, city planners, and citizens need to move decisively to save and restore wetlands, viewing them not as wastelands but as critical infrastructure for resilience to climate change, water security, and human well-being (Poudel et al., 2024; Abhinay et al., 2024; Mukherjee et al., 2023).

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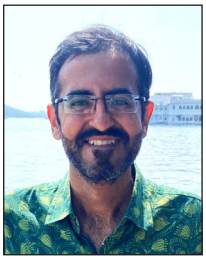
Knowledge Session on "Building Technologies for Future of Cities – Dust Free Construction"

A Knowledge Session on "Building Technologies for Future of Cities – Dust Free Construction" was organised on July 4, 2025 at New Delhi by BMTPC in collaboration with Indian Institute of Architects (IIA) Northern Chapter. The session was specially curated for practicing architects and aimed at providing them with a unique opportunity to learn about emerging construction technologies and interact directly with technology providers. The event witnessed the enthusiastic participation of nearly 100 practicing architects/professionals.

The session featured technical presentations by industry partners who presented their innovative construction solutions, highlighted advanced building technologies and materials with focus on dust-free and resource-efficient practices at construction sites. M/s NCL Industries Limited presented their product Cement Particle board & M/s Multi Decor India Pvt. Ltd presented Pre-engineered Steel Structures and Light Gauge Steel Frame technology. Finally, there was interactive session for knowledge exchange and about the practical application of the showcased technologies in future projects.

Towards a new Construction Paradigm



Sugeet Grover *

Introduction

The building and construction sector is one of the largest contributors to global greenhouse gas emissions. In 2023, this sector, including embodied carbon, was responsible for 34 per cent of global energy-related CO_2 emissions and consumed a similar share, 34 per cent, of total global energy demand.[1] India mirrors this trend. The Bureau of Energy Efficiency (BEE) estimates that buildings account for more than 30 per cent of the nation's energy consumption[2], and this demand is rising at about 8 per cent annually[3]. This growth in energy consumption is tied closely to the rapid expansion of India's building stock.

If building practices continue unchanged, this will lock the country into decades of high energy consumption and material-related emissions. However, as per multiple estimates, between 40–50[4, 5] per cent of the buildings that will exist by 2050 in India are yet to be built. This represents an opportunity for us to align and calibrate our construction paradigm to reduce its environmental footprint.

From Tradition to Modernity: The Shift in Building Materials

Over the centuries, construction technologies evolved in response to local conditions, drawing on the resources naturally available in each region. Materials were adapted and refined over time, creating diverse, non-homogeneous systems designed for specific geo-climatic settings, with every component performing a distinct function.

Take the example of a cob wall: it combines soil: made up of sand, silt, gravel and clay, with thatch, lime and water. Clay binds the mixture, while sand provides strength. Thatch, sourced from local vegetation or agricultural waste, adds tensile strength to prevent brittleness and cracking, and also improves insulation. The wall, built up layer by layer, is finished with a plaster of fine clay or sometimes lime, which seals and protects it. Where required, a coat of linseed oil can be applied for extra water resistance. Each of these elements is essential to the system's performance in its setting, ensuring low embodied energy and maintaining thermal comfort for occupants.

Later, construction moved towards homogeneous materials such as burnt red brick, fly-ash brick and monolithic concrete. These newer materials, though strong and structurally reliable, often lack the multi-functional qualities of earlier systems. For instance, while concrete offers good structural stability, it performs poorly in delivering thermal comfort and energy efficiency. This rapid shift to homogeneous materials has occurred with little consideration of its impact on building occupants as well as the wider environment.

The CPWD Guidelines For Sustainable Habitat, 2014 includes a section on CPWD sustainability index. It lists down multiple parameters that a material should perform well upon for being used in a project. These include, recycled

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content, embodied energy, rapidly renewable, locally available materials, construction waste management etc. Most conventional construction materials however are unlikely to perform well on these metrics. Moreover, the raw materials used in these products carry their own serious environmental costs. Sand and aggregates, the essential ingredients of concrete, are among the most mined resources in the world, accounting for nearly 69–85% of all annual mineral extraction[6]. Their escalating demand has already led to a six-fold rise in global sand trade over the past two decades, putting immense pressure on rivers, coastlines and fragile ecosystems. Steel, another construction mainstay, comes with very high embodied energy, while the production of burnt bricks consumes large amounts of fuel, releases air pollutants and depletes fertile topsoil, permanently damaging land productivity.

Cement, the key component of concrete is particularly carbon-intensive: massive kilns burn fossil fuels and emit greenhouse gases, releasing almost 0.8 kg[7] of carbon dioxide for every kilogram of cement produced. Globally, a person ends up using more than 500 kg of cement on average in a year.[8] If the cement industry were a country, it would rank as the world's third- or fourth-largest emitter of carbon dioxide.[9] In 2022 alone, global cement production released about 1.6 billion tonnes of CO_2, nearly 8 per cent of the world's total emissions.[10]

Together, these non-renewable, non-regenerative materials make conventional construction deeply resource- and carbon-heavy, raising serious concerns about the long-term sustainability of current building practices.

Sustainable construction materials, a key component for India to achieve its targets

India's long-term low-carbon development strategy highlights that national power demand can be cut substantially by 2030 through improvements in the energy efficiency of building design, construction, and operations. It also underscores the importance of selecting sustainable construction materials and methods to meet this goal. In addition, the India Cooling Action Plan sets a target of achieving "thermal comfort for all," for which appropriate material choices will be critical.

The Indian construction sector emits about 500 million metric tons of CO_2 each year from embodied carbon alone, and this figure is expected to double as urbanization accelerates.[11] Construction materials such as cement and steel will be major contributors to this. Studies project that India's demand for cement and steel could soar to 1,360 million tonnes (MT) and 755 MT by 2050, up from 328 MT and 99 MT in 2019, respectively[12] if conventional practices continue. This highlights the urgent need to rethink how construction materials are used to ease future environmental and resource pressures. Cutting emissions from the building sector is also critical for India to meet its climate commitments, including a 45 per cent reduction in the emissions intensity of GDP by 2030 and achieving net-zero carbon emissions by 2070.

Material choices will therefore be central to shaping the carbon intensity of future building stock, influencing both the embodied carbon of construction materials and the operational energy use of buildings. Without major improvements in material efficiency and energy performance, meeting national targets will be challenging, underscoring the urgent need to adopt low-carbon alternatives and sustainable construction practices.

The construction sector needs to be moulded to support India's national goals

The construction paradigm needs to be moulded and reimagined so it supports India's long-term climate and development goals. By shifting the focus from speed to enduring performance, the sector can embrace materials and methods that balance rapid growth with environmental responsibility. Using low-carbon, thermally efficient alternatives will improve indoor comfort, cut energy demand, and reduce reliance on mechanical cooling. At the same time, attention to both embodied carbon and operational energy can help the building stock contribute to the national targets. This transformation offers an opportunity to create buildings that are comfortable, resource-efficient, and climate-aligned, setting the foundation for a resilient urban future.

India's Long-Term Low-Carbon Development Strategy recognizes the need to improve energy and resource efficiency, with efforts to increase the use of natural and bio-based materials. It also mentions the need to enhance material efficiency and recycling, strengthening the circular economy. To align with this, we need to recognize and adopt alternatives that exist in the market.

To move in this direction, it is essential to acknowledge and adopt the alternative building solutions already available in the market. Here, the Building Material and Technology Promotion Council (BMTPC) plays a pivotal role and has made notable progress in recent years.

BMTPC has actively promoted bamboo-based technologies, particularly in the North-Eastern Region and other bamboo-growing areas. In collaboration with the Indian Plywood Industries Research & Training Institute (IPIRTI), Bengaluru, it developed bamboo mat corrugated roofing sheets, a technology that combines strength with sustainability.

To showcase the potential of bamboo based technologies, BMTPC has constructed 25 demonstration structures across Mizoram, Tripura, Nagaland, Meghalaya and Manipur, including houses, OPD buildings, libraries, picnic huts, schools and gazebos.

In 2021, BMTPC and the CSIR–Central Building Research Institute (CBRI), Roorkee jointly released the Compendium on Building Technologies, which catalogues 66 proven technologies across categories such as flooring and roofing systems, wall and foundation construction, system-level solutions, services and materials. This publication focuses on low- to mid-rise individual housing and highlights both traditional and neo-sustainable methods like rammed earth, compressed earth blocks and kath kuni walling.

The same year, BMTPC brought out the Compendium of Indigenous Innovative Building Materials and Construction Technologies, documenting 73 owner-driven technologies suited to single- and double-storied houses built either by homeowners themselves or by local masons and artisans. This compendium also emphasizes how such technologies can generate local employment, recognizing job creation as a key feature of sustainable construction practices.

As more low-carbon alternatives are developed and gain visibility, it becomes essential to sustain efforts to create widespread awareness about their benefits and potential applications. This awareness must be accompanied by a strong push to integrate these materials and technologies into the mainstream construction industry.

Learning from those who have kept these non-conventional alternatives alive

Several institutions and practitioners are now championing low-carbon construction alternatives that merge traditional wisdom with modern engineering. Fusion technologies combine the structural strength of contemporary materials with the thermal and ecological benefits of age-old practices, for instance, using cob or adobe walls as infill within a reinforced frame to achieve both durability and natural insulation.

A small but growing number of architectural firms are experimenting with such hybrid approaches, showing that sustainable construction can be modern, visually striking and highly desirable, rather than merely a low-cost option for rural housing. Their pioneering projects are gradually reshaping public perceptions of what sustainable design can achieve.

Supporting this shift, research from CEPT University, CSIR-CBRI Roorkee and IISc Bengaluru has validated the strong thermal performance of materials such as compressed earth blocks, stabilized rammed earth and adobe blocks. These studies supply the standardized data needed for inclusion in building codes and guidelines, helping move these low-carbon materials from the margins into the mainstream of construction practice.

Materials, technologies that show promise

It is important to understand that the viability of using a material–technology in a particular region should depend on several interlinked factors. These include the availability of component materials locally, the material's response to the region's geo-climatic conditions, and its resilience to extreme weather events or natural disasters such as floods, earthquakes, or high winds. Equally crucial is the ability of the chosen system to provide thermal comfort across seasons and reduce the need for mechanical cooling or heating. In addition, the presence of skilled labour familiar with the construction method, or the possibility of training local workers, plays a key role in ensuring that the technology can be implemented effectively and maintained over time. Together, these considerations determine whether a material–technology can truly be viable and sustainable within its specific regional context.

The Centre for Science and Environment's recent publication, "Beyond Concrete: Low-carbon Solutions from Novelty to Norm"[13] is an effort to guide the transition towards sustainable building practices. It showcases over 20

non-conventional construction technologies, offering step-by-step guidance for several of them, and outlines policy pathways that can help stakeholders bring these lesser-used methods into the mainstream of construction practice. It lists down low-carbon techniques in the categories of walling, intermediate floors, roofs, roof coverings and others. While some of these construction technologies find their origin in traditional construction, all of them have also been used in modern buildings as well.

Rammed Earth Construction

Construction of rammed earth walls involves compacting subsoil that has an optimum moisture content and contains suitable proportions of sand, gravel and clay, with or without cement stabilization. The prepared soil mix is placed in formwork and compacted to roughly half of its original volume. The soil is packed in layers or courses to gradually build the wall up to the top of the formwork. The compressive strength of rammed earth depends on several factors including the type of soil, particle size distribution, level of compaction and moisture content.[14]

Compressed earth blocks

Compressed earth blocks (CEBs) are produced from a mixture of soil, sand and water, and can be stabilized with up to 5 per cent cement to increase strength, in which case they are called compressed stabilized earth blocks (CSEBs). They are pressed manually or mechanically and then cured for 28 days. The blocks can be made solid, hollow, round or in customized shapes depending on the intended use, and are suitable for walls, columns, floors and even roofs. Because site soil can often be used, transport costs are lower, though their feasibility depends on the suitability of the local soil.

Compressed earth blocks

Cob Wall

This type of wall is built using a mixture of soil (including sand, clay and silt), straw and, in some cases, lime. Clay in the mix acts as the binder, sand provides strength, and straw reduces brittleness by adding tensile strength. Straw also improves the wall's insulating properties. The exact proportions and composition of the mixture depend on the type of soil available. The wet soil mix is laid in horizontal layers and allowed to dry before the next course is added.

Cob Wall

Source: https://thebetterindia.com/358205/tiny-farm-fort-homestay-rishikesh-raghav-ansh-kumar-delhi-architects-cob-sustainable-home/

Adobe Blocks

Adobe blocks are made from clay-rich soil mixed with straw and can be stabilized with lime or cement. Traditionally, the mix is shaped in open moulds and left to dry in the sun. The blocks are laid with earth mortar and finished with a mud plaster. These bricks are fire-resistant, durable, and slightly flexible, and their high thermal mass ensures good energy efficiency and sound insulation.

Wattle and Daub

Wattle and daub construction uses a lattice of interwoven rods made from twigs, local wood, or bamboo splits, called the wattle. This framework is coated with daub, a plaster made from wet clay-rich soil mixed with cow dung and often straw. The soil used is generally more clayey than that used in cob walls. Wattle and daub walls are usually thinner, typically around 15–20 cm thick.

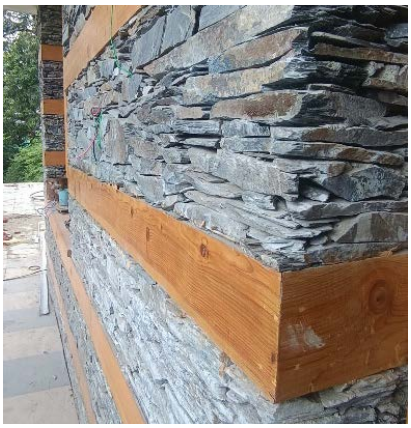
Rubble Masonry

Irregular-sized and shaped stones are used to create random rubble masonry wall. They are basically stacked and layered on top of one another and both mud and cement/lime mortar can act as binding materials.

Rammed Earth Construction

Adobe Blocks

Wattle and Daub



Rubble Masonry
Photo credits: Rajneesh Sareen and Sugeet Grover

It's cousin, ashlar masonry is a type of stone masonry which is formed using dressed stones of same size, shape and texture laid together in cement or lime mortar of equal size joints at right angles to each other and in level courses.

Bamboo mat wall panels

Bamboo mat boards are produced by soaking multiple layers of bamboo mats in resin and pressing them in a hot press. The resulting panels can be used as infill wall panels within an RCC or steel structural frame, as well as for false ceilings, partitions, walling, and wall paneling. These products are certified in accordance with the relevant IS codes.

Agrocrete blocks, bio bricks and hemp-crete blocks

Several types of construction blocks now available in the market are made using biomass or crop residues such as paddy straw, cotton stalk, bagasse, and hemp. These solid blocks are lightweight and often provide better insulation than conventional bricks.

Bamboo mat wall panels
Source: https://bamboosocietyofindia.com/venu-kutir

Agrocrete blocks, bio bricks and hemp-crete blocks
Source: https://greenjams.org/wp-content/uploads/2022/12/Rishikesh-Project-2-e1671819686828.jpg

Shallow Dome

A shallow dome, such as the Rohtak dome, is a gently curved roof with a low rise, creating a

Shallow Dome
Source: https://www.rohtakdome.com/

soft, wide arch rather than a tall, rounded shape like a traditional dome. From the outside, it appears as a slightly curved surface but is strong enough to cover large areas without the need for beams beneath. It can be adapted to different plan shapes and, compared to the time required for curing an RCC slab, it is quicker to construct and ready for use.

Jack Arches

Jack arches are a method of constructing flat or gently arched floors and roofs using masonry units such as bricks or stone. Despite their flat appearance, they function structurally as a series of shallow arches, each spanning between parallel load-bearing beams, typically rolled steel joists, timber beams, or masonry walls. The bricks in each arch are laid in a slightly curved profile so that all the masonry works in compression, the natural strength mode of brick and stone. Because arches transfer

Poured earth concrete

loads primarily through compression to their supports, tensile stresses are minimal, eliminating the need for reinforced concrete or structural steel within the arch itself.

Poured earth concrete

In this technique, semi-liquid soil is poured into formwork much like concrete. The soil needs to be sandy or gravelly and must be stabilized. However, this method is rarely used because the high water content leads to significant shrinkage during drying, which often causes extensive cracking in the walls. The technology is still in the development stage.

CSEB-Concrete composite: beams, columns and lintels

Compressed earthen blocks maybe used to partially replace their concrete counterparts. A beam for example can also be made partially from CSEB while the part that holds steel uses concrete. The beam is precast on ground and the concrete portion is also casted

Jack Arches

CSEB-Concrete composite: beams, columns and lintels

on ground. The same technique is used for lintels. Composite columns have also been developed in which only a small part section is taken up by concrete while the rest is CSEB block.

Towards a less carbon intensive future-construct

Moving beyond conventional construction requires a paradigm shift. It means rethinking not only the materials we use but also the values driving construction. Speed and standardization have dominated decision-making, but sustainability, comfort, and long-term performance must take precedence.

The answer will lie in picking up the 'wisdom to build' inherent in local construction and merging it with the convenience and durability that is achieved by modern construction practices while also embracing new low carbon materials and technologies evolving in the fringes. A form of hybridization that not only reduces our reliance on high embodied energy construction methods, but is also practical and accessible

The future lies in hybrid approaches that integrate traditional wisdom, modern engineering, and emerging low-carbon technologies. This is not about rejecting concrete entirely but reducing its dominance. By using it strategically in structural elements while adopting better walling and infill materials, we can significantly cut embodied carbon and improve comfort.

Policy support will be critical, governments should expand building codes to include non-conventional technologies, incentivize low-carbon materials, and promote awareness campaigns for homeowners and developers. Large-scale programs like PMAY should prioritize thermal performance and embodied carbon reduction, setting clear criteria for material use. Financial institutions can also support the transition by offering green finance products that reward sustainable construction.

Equally important is investment in training and capacity building. Local masons and builders must be equipped with the skills to implement hybrid and alternative technologies effectively. This will not only preserve traditional knowledge but also create new livelihoods. Academic and research institutions must continue generating performance data to validate and improve these materials.

Ultimately, the way forward is not about one-size-fits-all solutions. Local climate, resources, and skills must shape construction choices. By merging indigenous practices with modern durability and innovation, India can build in a way that is climate-appropriate, resource-efficient, and socially inclusive. This transition is essential not only to meet national climate goals but to ensure that homes and cities of the future are comfortable, affordable, and resilient.

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From Chaos to Care: Shaping Resilient Cities for Tomorrow


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Mother earth has evolved over a period of billions of years and has acquired the present shape and features having witnessed many very long turbulent spells of the natural phenomena. Ever since the human beings have started to understand scientific reasons for evolution and natural phenomena, the world has seen rapid growth in very possible sphere. It has also seen exponential growth in population as the scientific and technology advancements have improved quality of living, though there are still many countries that are yet to see such improvements.

The growth in world population has been worrisome. It has not only taken toll on the natural resources and the habitable landmass, it has also put tremendous pressure on further researches and developments to find out solutions to the related problems that may turn into crises in future. A few have already acquired dubious status.

It is a well-known fact that the earth has only about 29.2% surface that has habitable land, wasteland (deserts etc) and forests. The habitable land is for human dwellings and agriculture purposes. According to an estimation the habitable land is sufficient only for 1.5 to 2 billion people whereas at present, the world population is about 8.3 billion. This single fact is enough to understand enormous pressure that the natural resources have been facing, and the imbalance caused to the ecosystem. Rapidly spreading urban areas have been one of the culprits as well, though it has been a necessity, and has many positives too.

Of the total land surface, 10% is covered by the ice sheet, 33% is desert, 24% is hilly and mountainous and 10.7% is arable land. Only a little more than one percent is used as urban infrastructure. In terms of the habitable land that support communities, 50% land is arable to feed bulging population, 37% land has forests, 11% is grassland and again just over one percent habitable land is urban areas. Thus, it can be easily determined and concluded that a large portion of the population is still living in the rural areas. The UN figures show that in 2020, 56% of the population was living in the urban areas where as it is expected to rise to 68% by 2050. About 37% urban centres have the population of less than a million, 18% have the population between 1 to 10 million people and 7% have the population more than 10 million people. The pace of urbanization is alarmingly fast and therefore the question of sustainable, environment friendly and growth-oriented urbanization becomes relevant.

Urbanisation in many under developed and over populated countries such as India and other South Asian countries is an inescapable root to development as it comes with many benefits. A few of them are:

1. Economic growth centres
2. Job creation due to manufacturing and service industries
3. Enhancing efficiency and innovations
4. Improved quality of life

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5. Greater access to high quality of education, healthcare facilities and information sources.
6. Cultural exchange fostering social advancement and creativity & harmony.
7. Infrastructure development such as transportation system, communication networks and public services.
8. Technology innovation.

World over, the major civilizations have come into existence where the basic natural resources were available - water, flat land, natural routes, etc. The same rule applies when urban areas take shape. All metropolitan cities in India and abroad have been either on the river banks or near sea shores. Even for the industries to come up water is essentially needed.

50 years ago in India, over 80% population was living in the villages as against the present figure of 70%. There was a growth of 31.02% in the urban areas between 1991 to 2001 and as of 2011 the total urban area was 31.16%. These figures abundantly and explicitly show the pace of urbanization in India, somewhat similar to that of the African continent.

However, the urbanization has come at a massive cost that has been badly affecting the lifestyle of those living in such areas. Technical advancement and scientific progress have produced or rather inventor multiple products that have been responsible for greenhouse effect and various pollutions. Adding to it is ill- planned or unfordable housing. However, depleting green covers and water, potable water and wastewater both, top the list of the issues that require immediate attention and response.

1. Water

Water is scarce. Yet solution lies in tapping all available water resources. The biggest resource for India is the monsoon water. Normal monsoon brings about 3000 billion cubic metres of water of which only 85 billion cubic metres of water could be tapped or stored. Therefore, the groundwater level recharging should be given the utmost importance. Every building must have rainwater harvesting system in place where the maximum water sliding down the roof must be channelise to a place where a very deep borewell is dug. Similarly, major cities where the water logging has become a new normal, should also identify such problematic areas and water harvesting system like storm water channels, rain gardens, must be placed there.

Rivers have been the major source of water. Most of the rivers, however, cause floods where as many either remain dry or have inadequate water even during the monsoon. River linking is a permanent solution. China is taking water by way of river linking from its southern part to the heavenly populated Northern region. It must be emulated in our country as well by diverting the funds received from the industrial conglomerates under the CSR scheme. The Narmada River water has been taken to the Sabarmati River and further to Barmer in Rajasthan. The Pattiseema Lift Irrigation Project has linked the Godavari and the Krishna rivers to transfer surplus Godavari water to the Krishna river.

Such rivers linking will definitely enhance irrigable land area and support supply of the potable water to the nearby urban areas and villages. It will also lead to somewhat equitable development of the industrial zones.

The connected issue of the wastewater management, both the domestic as well as industrial, must be strictly implemented before that water is released into any nearby rivers or water bodies. Recycling of water will drastically reduce river pollution.

2. Garbage disposal

A huge colony has been developed with solid garbage used as its base or foundation in Indore that

has been maintaining its winning streak as the cleanest city in India. It was appreciated world over for innovative thinking and implementation. Garbage recycling plants are the need of the hours that should convert biodegradable refuse into compost or manure to be used to improve upon fertility of the arable land. Use of plastic products must be minimised or rather band and their waste should be used in developing building materials (low cost). New Delhi has a huge pile of dumped garbage, other major cities too are grappling with this problem. A clue from the other countries may be had to get permanent solution to this issue.

Barmer in Rajasthan has adopted a system where the bags made of used and discarded clothes are used by the shopkeepers instead of polythene bags. Another example is a society in South Delhi, Navjeevan Vihar, that produces zero waste be it biodegradable or non-biodegradable waste. All the kitchen or biodegradable waste is turned into compost whereas textile waste like discarded clothes are collected in a clothe-box and are made accessible to the ones in need.

"A society that manages its waste responsibly, manages its future responsibly."

Spreading awareness in this regard is another step that can be taken. It should start from the basic / elementary schooling.

3. Air Pollution and Urban Health

Step outside on a winter morning in Delhi and experience more than just mist, it's a thick grey haze that stings the eyes and makes every breath feel heavy. This is not unique to Delhi. Lahore, Dhaka, and many other cities live under the same suffocating blanket of smog, while faraway places like Los Angeles and London also struggle with their share of polluted skies.

According to the World Health Organization, 99% of the urban population breathe air that is unsafe. That means almost every child walking to school, every office worker on their commute, and every elderly person sitting by a window is inhaling pollutants far beyond safe limits. The consequences are not abstract, they show up as asthma attacks in children, heart problems in adults, and millions of premature deaths each year. The Lancet estimates that 6.7 million lives are cut short annually because of polluted air.

What's behind this crisis? The answer is painfully familiar—endless traffic jams, smoke-belching factories, and dust from relentless construction. It is a price that cities are paying for rapid growth and unplanned development.

But there is hope, and cities around the world are proving it. Copenhagen and Amsterdam have turned cycling into a way of life proving that healthier commutes are possible. Shenzhen in China runs the world's first fully electric bus fleet carrying millions daily without adding to smog. Beijing, once infamous for its choking air, has introduced strict emission norms and real-time air quality monitoring showing that determined policies can make skies clearer.

Example: Shenzhen converted its entire bus fleet to electric.

The fight against air pollution is not just about statistics—it is about the right to breathe freely. Cleaner transport, stricter regulations, and smarter urban planning

are not luxuries. They are necessities because every lungful of clean air is a step toward healthier and longer lives.

4. Affordable Housing and Informal Settlements

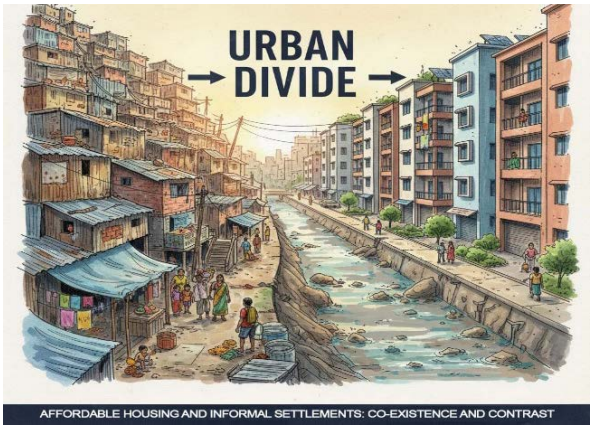
Imagine coming home after a long day only to find that the "home" is a one-room shack with leaky tin sheets, no running water, and the constant fear that a fire, flood or eviction could take it all away. For more than 1 billion people worldwide, this is not imagination, it's a daily reality.

In India, one in three urban residents lives in a slum, navigating narrow lanes where families share community taps and toilets. In Lagos, Nigeria, the numbers are even starker with over 60% of people living in informal settlements that spring up faster than governments can plan for them.

The crisis isn't simply about a lack of houses. It is about land that is too expensive, real estate that is driven by speculation instead of need, and relentless migration as people move to cities in search of better lives. The result: overcrowded, unsafe settlements where basic dignity—sanitation, clean water, secure shelter—is a luxury.

"Housing is not just about shelter, but about dignity and inclusion."

And yet, there are rays of hope. Mumbai's Dharavi redevelopment project, though controversial, shows the possibility of transforming slums without uprooting livelihoods. In Brazil, the "Minha Casa, Minha Vida" programme has already given over 10 million families a roof they can call their own. Singapore's Housing Development Board (HDB) stands as a



AFFORDABLE HOUSING AND INFORMAL SETTLEMENTS: CO-EXISTENCE AND CONTRAST

global model—proof that with the right policies, public housing can be dignified, affordable, and inclusive.

Affordable housing is more than brick and mortar. It is about giving people security, health and a chance to dream beyond survival. Cities that rise to this challenge do not just build homes they build hope.

5. Urban Mobility and Transportation Crisis

For millions of city dwellers, the day begins and ends in traffic. A young professional in Bengaluru spends nearly three hours crawling through congested roads daily. A parent in Delhi rushes to drop their child at school only to get stuck behind endless rows of honking cars. For many, time lost in traffic is time stolen from family, rest and opportunity.

This isn't just inconvenience it is an urban crisis. Indian cities move at an average speed of just 18 km/


URBAN MOBILITY CRISIS: A CITY AT A STANDSTILL

hour during peak the hours, slower than a bicycle ride. The economic cost runs into billions, while the human cost is measured in stress, road accidents, and polluted lungs. The carbon emissions from millions of vehicles idling in jams also contribute heavily to climate change.

But solutions are emerging. Delhi, Bengaluru, and Jakarta are expanding their metro rail systems offering fast and reliable alternatives to the chaos above ground. In Curitiba, Brazil, the Bus Rapid Transit (BRT) system—simple, affordable, and brilliantly planned has become a global model, later inspiring cities like Ahmedabad to rethink its public transport.

New technologies are reshaping mobility too. Ride-sharing apps reduce the number of vehicles on roads. Experiments with autonomous vehicles hint at a future where commuting is safer and more efficient. Mobility-as-a-Service (MaaS) platforms are stitching together buses, metros, and bikes into a seamless urban travel experience.

Transport is more than moving people from one point to another. It is about dignity, safety, and time. A city where its people can travel easily is a city where opportunities open up, air is cleaner and life feels just a little less hurried.

6. Energy and Resource Management

Picture a bustling city at night—streets lit up, offices glowing, trains running, and homes buzzing with

Energy isn't just about powering machines, it is about powering lives. A reliable, clean energy supply means a child can study at night, hospitals can save lives without disruption and businesses can grow sustainably. Cities that embrace renewable energy are not just reducing carbon, they are giving their people light, resilience, and hope for the future.

fans, refrigerators, and Wi-Fi routers. It's easy to forget that behind this comfort lies an invisible crisis: cities consume three-quarters of the world's energy and generate over 70% of carbon emissions.

When a blackout hits, the crisis becomes real. In Mumbai, entire neighbourhoods swelter in the dark during summer outages. In Lagos, families often rely on noisy, polluting diesel generators. And in many parts of Africa and Asia, children still study by candlelight because the grids do not reach their homes.

The demand for cleaner and more reliable energy is urgent. The world cannot keep burning fossil fuels and expect breathable air and a stable climate. Encouragingly, cities and nations are showing the way forward. Germany's Energiewende programme is pushing a nationwide shift to renewable energy while India's Gujarat rooftop solar scheme has turned countless homes into mini power stations.

In Sweden, waste is no longer just garbage it is a fuel. The country is so efficient at turning waste into energy that it even imports trash from neighbouring nations to power its grids. Across African countries, decentralized and community-owned solar projects are lighting up villages and towns, bringing electricity to places long ignored by national grids.

7. Climate Change and Urban Vulnerability

In Jakarta, families watch the sea creeping closer each year. Some neighbourhoods are already below water level forcing children to walk on raised planks to reach school. The city is sinking so quickly—25 centimetres a year—that Indonesia has begun planning a new capital altogether.

Far away in Chennai, residents know the other side of the climate paradox. In 2015, homes were washed away in devastating floods; just four years later, in 2019, the same city ran out of water and its lakes and reservoirs cracked dry. The swing from too much to too little showed how fragile urban systems can be when natural ecosystems are ignored.

These are not isolated stories. They are the lived realities of cities everywhere. Heatwaves in Paris, hurricanes in New York, wildfires near Sydney—climate crises are hitting urban areas hardest because that is where people, infrastructure, and economies are concentrated.

Yet, cities are also proving they can adapt. In Rotterdam, Nether-

lands, green roofs and restored wetlands absorb stormwater, turning nature into a shield. In Tokyo, Japan, massive underground flood tunnels – the "G-Cans Project" protect millions from sudden deluges. And in Medellín, Colombia, cooling corridors lined with trees have helped fight back the deadly heat trapped in concrete jungles.

Climate resilience is not just about engineering. It is about survival. When cities build with nature, invest in resilient infrastructure and plan for rising risks, they give their people more than safety. They give them a fighting chance against an uncertain future.

8. Governance and Institutional Response

When a city fails, it is rarely because of a lack of ideas. It is usually because of weak governance. Fragmented agencies, overlapping powers, and chronic underfunding leave urban residents paying the price in floods, pollution and unsafe housing.

India has seen this clearly in recent years. During the 2023 Bengaluru floods, gated communities and IT campuses were submerged, not because rains were unprecedented, but because stormwater drains had been encroached upon and planning authorities failed to coordinate. In Delhi, the struggle between multiple governing bodies—municipal corporations, the Delhi government, and central agencies—has slowed efforts to

tackle waste, air pollution, and traffic congestion. Even in Chennai, experts say that poor governance and political disputes have deepened the city's swings from flood to drought.

But governance can be a powerful solution. Around the world, some cities show how strong institutions can build resilience. In Seoul, South Korea, citizens take part directly in shaping their city through participatory budgeting, deciding how portions of municipal funds should be spent. In Kigali, Rwanda, strict governance on cleanliness and a ban on plastics have turned it into one of Africa's cleanest capitals. And through the "100 Resilient Cities" initiative, supported by the Rockefeller Foundation, urban governments have been given tools to prepare for shocks—whether climate disasters, pandemics, or economic crises.

Ultimately, resilience isn't just about infrastructure. It is about trust. People need to believe their city will protect them and that requires transparent governance, accountable leadership and institutions that put citizens first. A well-governed city is not only safer it is also a place where people can hope, plan, and build their futures with confidence.

9. Citizen Participation in Urban Crisis Response

No urban crisis can be solved by governments alone. The pulse of a city lies in its people and time and again, ordinary citizens have shown extraordinary resilience. From street protests to community clean-ups, it is often grassroots movements and local initiatives that spark real change.

In India, recent years have given us powerful examples. When Bengaluru's lakes caught fire due to unchecked pollution, it was citizen-groups like the "Save Bellandur" campaign that pressured authorities into action. In Mumbai, fishing communities have been at the forefront of resisting unchecked coastal development, reminding the city that livelihoods and ecosystems are deeply intertwined. During the 2023 Chennai water crisis, resident welfare associations took charge of rationing and reusing water, turning neighbourhoods into models of conservation. And across Indian cities, from Gurugram to Pune, citizens' clean-up drives have filled the gaps left by municipal waste management.

Globally too, people-led initiatives inspire. In Ahmedabad's slums, self-help groups of women pioneered savings schemes to build toilets and improve sanitation. In Bogotá, Colombia, the Ciclovía turns streets into car-free zones every Sunday, giving citizens a chance to reclaim public space for cycling, walking, and community bonding. Meanwhile, urban farming movements in Detroit and Havana show how abandoned land can be transformed into sources of food security and dignity.

Citizen action is not just a supplement to governance. It is often the spark that pushes governments, businesses, and planners to act faster and more fairly. When people participate, cities stop being faceless machines and start becoming living communities where change is possible.

The Way Forward – Towards Sustainable and Resilient Cities

Urbanization is inevitable—but urban crises are not. Around the world, cities have shown that with vision, innovation, and community spirit, it is possible to build urban areas that are sustainable, resilient, and deeply humane. The challenges before us are immense, but so is the opportunities.

1. Mainstreaming the Circular Economy

Waste does not have to be a burden, it can be a resource. Sweden runs waste-to-energy plants so efficiently that it actually imports waste from other countries to power its grid. Japan's zero-waste town of Kamikatsu has achieved over 80% recycling by involving citizens in carefully sorting household waste. These models show that circularity can transform urban metabolism.

2. Integrated Water and Waste Management

Cities like Singapore have

turned water scarcity into security with their "NEWater" initiative—recycling wastewater into potable water. Indore, often ranked as India's cleanest city, has shown how rigorous waste segregation and citizen participation can drastically reduce landfill dependency.

3. Affordable Housing and Inclusive Development

Housing is a right, not a privilege. Singapore's Housing Development Board (HDB) provides affordable, high-quality homes to 80% of its citizens, blending density with dignity. Brazil's Minha Casa, Minha Vida has delivered millions of homes for low-income families, while community-led upgrading in Medellín, Colombia, transformed dangerous slums into vibrant and connected neighbourhoods.

4. Strengthening Public Transport and Non-Motorized Mobility

Mobility shapes opportunity. Curitiba, Brazil, pioneered the Bus Rapid Transit (BRT) model, offering affordable, efficient mobility to millions. In Amsterdam and Copenhagen, cycling is not just transport it is a culture, supported by safe lanes and infrastructure. Indian metros like Delhi and Bengaluru have already demonstrated how MRTS can shift commuters away from private vehicles.

5. Investing in Renewable Energy and Climate-Resilient Infrastructure

Resilience must be built into the city's bones. Rotterdam, Netherlands, has combined engineering and ecology with floating neighbourhoods and water plazas. Tokyo's underground "G-Cans Project", a vast system of floodwater tunnels, protects millions from typhoons and floods. On the energy front, Germany's Energiewende shows how rooftop solar and wind energy can decarbonize even an advanced economy, while community-owned solar microgrids in Kenya light up villages with sustainable power.

6. Empowering Local Governments with Finance and Autonomy

Strong local governance delivers strong cities. Seoul's participatory budgeting allows citizens to directly decide how portions of municipal funds are spent, fostering accountability and trust. In Kigali, Rwanda, strict local governance on waste and plastics has made it one of Africa's cleanest capitals.

7. Fostering Citizen-Led Solutions and Community Ownership

At the heart of every great city are its people. In Bogotá, Colombia, the weekly "Ciclovía" turns streets into spaces for walking, cycling, and play, reclaiming urban life from cars. In Detroit and Havana, citizens transformed abandoned land into urban farms, ensuring food security and community pride. Across India, from Bengaluru's Save Bellandur Lake campaign to Chennai's rainwater harvesting revival, citizens have shown they are not passive beneficiaries but active city-builders.

8. Smart Villages to Ease Urban Pressure

The future of urban sustainability also depends on revitalizing rural areas. The Smart Village concept integrates digital technology, renewable energy, and sustainable livelihoods into rural life, reducing the need for mass migration to cities. In India, programs like Shyama Prasad Mukherji Rurban Mission (SPMRM) are creating "urban-like" amenities, i.e., clean energy, digital access, health, and education—while preserving rural strengths. Globally, China's smart countryside pilots have shown how e-commerce, telemedicine, and rural startups can provide jobs and reduce dependence on megacities. By strengthening villages, we can distribute development more evenly and relieve urban centres from unsustainable pressure.

Urban crisis response is no longer optional, it is the very condition for survival. With half of humanity already urban and millions more joining cities each year, the decisions we make today will decide whether cities become engines of sustainable progress or epicentres of collapse.

The way forward is clear: embrace global best practices, adapt them locally, invest in smart villages, and empower communities to lead. A circular economy, resilient infrastructure, affordable housing, clean transport, renewable energy, and citizen-driven governance can together reimagine the city as a place of dignity, equity, and opportunity.

The challenge is daunting. But the promise is more resolute. If cities are humanity's future, then by making both cities and villages resilient and just, we can ensure that they remain not only centres of growth, but true homes for generations to come.

"The future of humanity is urban." – UN-Habitat

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Green Rebar:
Turning India's Construction Backbone into a Catalyst for Low-Carbon Growth



Tarun Garg [1] *Harsha Pallerlamudi* [2] *Zoya Zakai* [3]

Green rebar offers a near-term, scalable pathway to decarbonise India's construction and steel sector by leveraging strategic interventions across the value chain

India's built environment is expanding rapidly, fuelled by rapid urbanisation and large-scale infrastructure development. At the heart of this transformation lies steel reinforcement bar, or rebar, the hidden skeleton that provides modern construction its strength.

Rebar belongs to the broader category of bars and rods, which in FY24 accounted for 42% (59 MT) of the country's finished steel consumption.[1] Demand is set to rise sharply as India's urban floor area is projected to more than double to 35 billion square metres by 2040.[2] With reinforced cement concrete (RCC) expected to remain the dominant construction method, rebar has become not just another steel product but the structural backbone of India's growth, embedded in virtually every residential, commercial, and infrastructure project.

This growth also carries a significant environmental cost. Steel contributes an estimated 15–25% of embodied carbon in construction, emissions that can be locked into structures for decades, if neglected.[3] India's finished steel consumption is expected to nearly double to 230 MT by 2030, intensifying the urgency to decarbonise.[4] Recognising this, the Ministry of Steel has initiated a national decarbonisation roadmap and developed a Green Steel Taxonomy.[5] Given its scale, centrality, and performance requirements, rebar demands focused attention.

Recognising the scale and strategic importance of this opportunity, RMI India Foundation undertook a sectoral deep dive into rebar decarbonisation in partnership with Lodha Foundation under the Net Zero Urban Accelerator initiative.[6] Under the aegis of the G20 secretariat, RMI India Foundation also published a discussion paper on enabling steel circularity in India's built environment.[7] Over the past year, the team visited steel plants in Maharashtra, Tamil Nadu, and Telangana, covering both integrated facilities and MSMEs and hosted webinar series to convene stakeholders across the value chain to discuss barriers and opportunities for low-carbon rebar. The series offered an integrated perspective on the demand and supply dynamics of green steel, underscoring the market, policy, and technological shifts needed to accelerate the scale-up of low-carbon rebar.[8]

The forthcoming report, ***The Rebar Opportunity: Decarbonising the Backbone of India's Built Environment***, underscores rebar's pivotal role in India's steel decarbonisation. It evaluates the sector's readiness for a green transition and quantifies the impact of key decarbonisation levers such as scrap utilisation, energy efficiency, and renewable energy. The report also projects future energy use and emissions intensity across steelmaking routes in line with the Ministry of Steel's 2030 targets. Finally,

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it outlines a strategic framework for producers, bulk buyers, and policymakers to scale and sustain a market for low-carbon rebar—setting the stage for a deeper examination of why rebar, more than any other steel product, can spearhead India's sectoral transformation.

Rebar Can Spearhead India's Steel Sector Transformation

Unlike many other steel products in India, which are predominantly produced via the blast furnace–basic oxygen furnace (BF–BOF) route, rebar is largely manufactured using electric furnaces. Small steel industries (SSIs) and standalone electric arc furnaces (EAFs) or induction furnaces (IFs) typically operate with scrap charge ratios of 40–80%, depending on scrap quality and availability.[9] About 70% of India's rebar already comes from this secondary route, with the remaining 30% produced by integrated steel plants (ISPs) through BOFs and EAFs.[10]

While breakthrough technologies such as green hydrogen and CCUS remain long-term solutions, scrap-based steel powered by renewables offers immediate emission reductions. Currently, EAF/IF-based rebar production emits roughly 2 tCO_2 per tonne.[11] With greater scrap utilisation and renewable integration, emission intensity could fall below 1 tCO_2 by 2030, and approach 0.5 tCO_2 by 2035 as the grid decarbonises further. Electric furnace pathway also avoids energy-intensive upstream processes such as sintering, pelletisation, and coking, resulting in lower emission (1.8–2.0 tCO_2 per tonne of rebar) compared to the BF–BOF route (2.7–3.0 tCO_2 per tonne of rebar).[12]

Maximising Scrap and Renewable Energy are Key Near-Term Levers for Rebar Decarbonisation

Green rebar represents an immediate, pragmatic pathway to decarbonise India's construction value chain. The pathway to green rebar lies in two high impact interventions: maximising scrap utilisation and increasing renewable energy penetration.

Increasing Scrap Recovery and Utilisation

India's ambitious developmental aspirations, and pursuit of Aatmanirbharata (self-reliance) depend not only on expanding steel production but also on transforming how steel is sourced, used, and recovered. Scrap is at the heart of this shift: every tonne of scrap reused in steelmaking avoids the extraction of virgin ore and coal, reduces energy and water use, and cuts emissions—making it one of the most effective levers for green steel.[13] Yet the supply of high-quality scrap has not kept pace with rising demand. A fragmented collection network, limited shredding capacity, and long product lifecycles have slowed recycling, forcing producers to rely on imports that are becoming costlier and less secure as exporting countries tighten retention policies. Simultaneously, pressure on iron-ore availability is reshaping input markets and increasing risks for secondary steelmakers, which dominate rebar production.

Strengthening India's scrap ecosystem—through vehicle-scrappage programmes, organised collection and shredding infrastructure, and circular-economy parks in scrap-rich states offers the clearest near-term pathway to bridge this gap. With proven refining technologies already enabling secondary producers to meet stringent quality standards for structural rebar, scaling high-grade scrap supply and processing can reduce raw-material costs, insulate the sector from trade shocks, and anchor rebar decarbonisation in a resilient domestic supply chain.

Increasing Renewable Energy Penetration

Since the rebar production is majorly through electric-furnaces, powering them with clean electricity can substantially reduce emissions without altering core processes, yet RE adoption remains limited. Current RE penetration in the steel sector is 7.2%, and captive RE use currently accounts for just 0.39%.[14] The Ministry of Power's target of a 43.33% Renewable Purchase Obligation (RPO) by 2030 is set to increase the share of renewables.[15] However, uptake is constrained by structural barriers in electricity pricing, largely due to subsidies, cross-subsidies, and tariffs that disincentivise small and medium scale industries (SMEs) from investing in clean power.[16]

Rationalised tariffs, open-access mechanisms, time-of-day incentives, and support for captive or group-captive projects can make renewable electricity more accessible and cost-competitive, enabling producers of all sizes to accelerate the transition to green steel. Such interventions could reduce power costs by 15–20% compared with standard grid tariffs.[17]

Overcoming Barriers to Scale Green Rebar: Quality, Transparency, and Cost as Key Enablers

Despite its advantages, green rebar faces persistent barriers linked concerns over the quality of rebar produced using high scrap, limited availability of high-grade scrap, electricity pricing structures that discourage renewable energy adoption, and the lack of reliable product-level emissions data. Overcoming these challenges is critical to place India's steel sector firmly on a credible net-zero trajectory.

Ensuring Quality and Building Market Confidence

Perceptions of inferior quality remain a barrier to the wider use of rebar produced with high scrap, despite meeting BIS standards. However, the Ministry of Steel does not distinguish steel products on input material or production routes but rather strict adherence to Bureau of Indian Standards specifications. Several quality control orders have reinforced this principle, and government departments have been directed to ensure adherence to the above clarification and avoid any restrictive practices in their tenders.[18]

Producers address quality concerns through systematic sampling, testing, and spectrometric analysis to confirm compliance with IS 1786. [19] Modern electric and induction furnaces apply refining techniques such as argon purging and ladle treatment to achieve precise chemistry, ensuring rebar made from high scrap content meets strength and durability requirements. Greater transparency through third-party certification and batch-wise traceability can further build confidence in recycled steel products.

Transparent Emissions Data is a Commercial Imperative

Credible product-level emissions data is fast becoming a prerequisite for green steel. Buyers need clear, verifiable footprints to inform procurement and meet their respective goals, but most steel producers lack comprehensive measurement and reporting systems. A few maintain operational emissions data at plant-level but lack systems that link it to specific product carbon footprints making emissions across grades or plants hard to compare. As trade regimes such as the EU's Carbon Border Adjustment Mechanism raise the stakes, reliable product carbon footprint disclosure will decide market access. Building a clear pathway from measurement to credible product carbon footprint estimates can help producers prove performance, strengthen buyer confidence, and turn transparency into a source of commercial advantage.

Decarbonisation Can Be Cost-Effective, Not Prohibitively Expensive

The perception that decarbonising rebar makes it prohibitively expensive often overstates the challenge. In reality, higher scrap usage, renewable electricity integration, and process efficiency gains can offset much of the cost, bringing the effective premium closer to 5–7 percent. Scrap substitution reduces reliance on high-cost virgin inputs while requiring careful sourcing of high-grade scrap. Energy costs are both a challenge and an opportunity, as electric furnace routes consume more electricity than conventional routes, but access to renewable power can deliver meaningful savings. Operational improvements and by-product valorisation, from slags in cement and road construction to recycled mill scale and flue dust, can reduce costs further and generate additional revenue streams. The barrier is not technical or financial infeasibility, but the absence of mechanisms to absorb even modest premiums across the construction value chain. With supportive procurement, contracting, and financing practices, India can scale low-carbon rebar production while meeting domestic and global green steel demand.

A Coordinated Strategic Framework Across the Value Chain Can Unlock Green Rebar at Scale

Rebar offers something rare in climate action, a near-term, scalable solution that doesn't require waiting for breakthrough technologies. The electric furnaces exist, scrap supply can be organized, renewable energy is available and quality standards can be met. Strategic coordination to connect these pieces into a coherent market transformation that aligns economic incentives with climate objectives is essential. The forthcoming report outlines a strategic framework to align producers, buyers, and policymakers in building the infrastructure for greater scrap recovery and in accelerating market adoption of green rebar.

- **Scale supply chain infrastructure:** Enhance scrap recovery from urban centres, establish circular economy parks and integrate efficient sorting and refining mechanisms.

- **Set performance specifications:** Integrate emissions thresholds, scrap content requirements, and renewable electricity use targets into procurement processes.
- **Aggregate demand:** Create buyer platforms and joint procurement efforts to signal strong demand.
- **Institutionalise through policy:** Embed EPD-based emissions criteria and scrap utilisation targets in policy, codes, tenders, and green public procurement.

Rebar is uniquely positioned to benefit from scrap-based steelmaking and electricity-driven decarbonisation to deliver immediate emission reductions. By maximising scrap use, integrating renewables, and improving transparency, India can scale green rebar production to meet domestic and global green steel demand. Unlocking its full potential requires coordinated action across the value chain to overcome barriers such as limited scrap supply, electricity pricing, quality assurance, data transparency, and perceived cost risks. With supportive infrastructure, procurement, and policy, Rebar can spearhead India's transformation to low-carbon steel, while laying the foundation for a net-zero future.Rebar offers a ready-now, scalable pathway to decarbonise India's rapidly growing steel sector, and expanding infrastructure to cater urbanisation, and net-zero commitments. Scrap-based electric furnace rebar delivers immediate emission reductions, leveraging established production routes, market scale, and manageable cost premiums through efficiency and renewable energy. Realising this potential requires coordinated action across the value chain. By aligning production readiness with strong demand signals, developers and policymakers can bridge industrial capability and climate ambition, transforming rebar into the spearhead of sector-wide steel decarbonisation.

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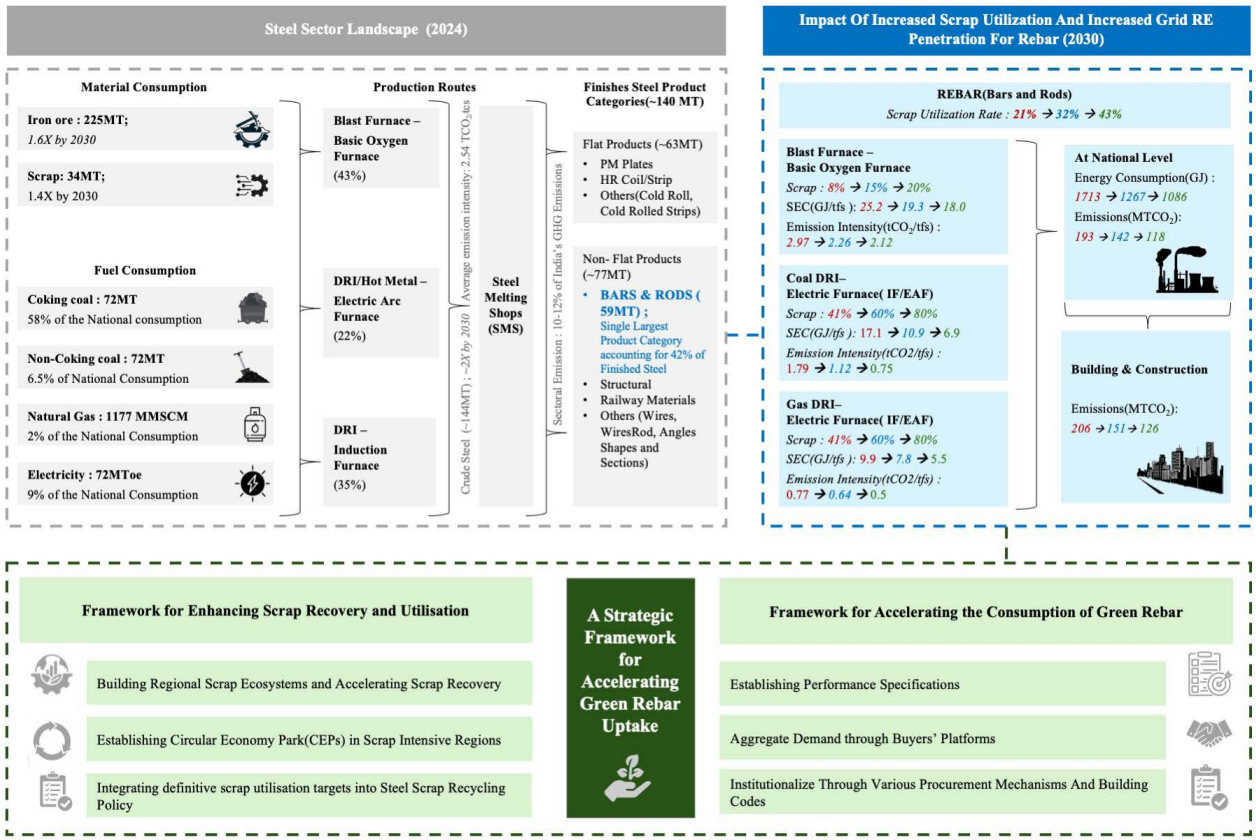
Exhibit 1: Strategic Framework for Accelerating Green Rebar Uptake



Note: MMSCM = Million Metric Standard Cubic Meters, SEC = Specific Energy Consumption
Note: 2030 Scenario (Average Scrap Utilization) : BAU (21%) à Scenario 1(32%)à Scenario 2(41%) ; The grid factors considered for the assessment are as per the GOI targets of RE penetration in 2030
RMI Graphic. Source: Ministry of Steel, Annual Report 2023-24, 2024
RMI Graphic. Source: Forthcoming report by RMI " The Rebar Opportunity: Decarbonising the Backbone of Built Environment"

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Beyond Heatwaves: Designing Indian Cities for Thermal Comfort and Equity

Alisha Abraham [1] *Ahona Datta Gupta* [2]

Sonu wipes the sweat off her brow as she cooks lunch for her two children in a small hutment in peri-urban Mumbai. The tin roof above radiates like a furnace, trapping the heat from the stove inside. A small fan whirs in the corner, circulating hot air from one end of the room to the other. Outside, the temperature is 36°C, but for Sonu and her children it feels even hotter.

Similar scenes can be witnessed across India's semi-formal settlements, where rising temperatures and frequent heatwaves pose daily risks to people's health and well-being.

Urban India is currently home to 35% of the country's population. Rising population density, concrete or asphalt infrastructure, and a lack of green spaces contribute to the Urban Heat Island (UHI) effect, further raising temperatures. Between 2003 and 2020, the nighttime land surface temperature of Indian cities increased at an average of 0.5°C per decade. With half of India's population expected to live in cities by 2050, meeting people's need for thermal comfort is a rising concern.

As people turn to coolers or air conditioners for respite, these devices can result in unintended consequences. Air conditioners transfer heat outside, where it raises local temperatures and intensifies UHI. Surging electricity demand from these devices during heatwaves drives up electricity bills, triggers outages and results in grid failures.

While heat affects everyone, its impacts are far more severe for vulnerable populations residing in overcrowded or poorly built dwellings that further trap heat. Women, elderly people and children living in these homes are particularly vulnerable to heat stress. Unable to afford effective cooling solutions, they can't even rely on electric fans due to frequent outages during heatwaves. Lack of indoor thermal comfort puts them at a greater risk of illness, forcing many to miss work and adding to healthcare expenses.

Heat stress is not limited to residential buildings either. It extends to workplaces — from construction workers and street vendors who face direct sun exposure to workers in buildings with high thermal gain. Sonu's husband, who works at a nearby construction site, often returns home dizzy and finds it difficult to work during the peak summer months. Prolonged exposure to high heat and humidity is also linked to reduced productivity and increases the risk of dehydration and fatigue among workers.

While cities have taken cognizance of the heat challenge and many have developed emergency heatwave measures, there is a need to ensure long-term resilience. Such efforts must also center equity and ensure thermal comfort among vulnerable urban communities.

Designing Buildings that Breathe

Conventional buildings, especially those under affordable housing schemes, are not built for thermal comfort. Poor housing design and usage of either high thermal mass materials — like concrete — or low albedo surfaces can significantly increase indoor temperatures. Passive cooling strategies such as building orientation and shading to reduce solar exposure, cool roofs to lower heat absorp-

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tion, and ventilation to improve air circulation, can significantly lower indoor temperatures. However, vulnerable urban communities are often either unaware or unable to afford these measures.

Interventions by organizations like Mahila Housing Trust (MHT) exemplify the impact of these strategies. Under their Cool Roof Program, the roofs of informal households were painted with solar-reflective paint. In some settlements, families reported that reflective paint finally made their rooms bearable in the afternoons, allowing children to sleep without constant discomfort.

Cool roofs are simple, cost-effective, easy to scale and reduce dependence on air conditioners. Several states now promote cool roof policies to ensure wider benefits. Buildings that house workers during the day can also integrate similar passive cooling strategies. In parallel, cities can shift outdoor work hours to cooler periods and establish shaded shelters where workers can rest and recover during peak heat.

Greening Cities for Equity

Low-income settlements are often excluded from urban greening efforts, resulting in dense, treeless environments. For example, a WRI India analysis found settlements with informal or low-income households in Mumbai to be 6 °C hotter than surrounding areas. Beyond incorporating passive cooling into buildings, urban blue-green infrastructure - parks, green roofs and wetlands - can also be employed to cool neighborhoods through evapotranspiration (land surface water loss through evaporation and transpiration). When tailored to local conditions and designed well, nature-based solutions (NbS) can help communities adapt to climate change impacts and help reduce multidimensional poverty.

The Brihanmumbai Municipal Corporation's (BMC) conversion of barren land in Marol industrial estate into an urban forest, reducing local temperature by over two degrees Celsius, is a remarkable example. Such efforts must ensure community participation for long-term success.

Policy Pathways for Heat Resilience

While several Indian states have been preparing and adopting heat action plans (HAPs), most focus on heatwave response, not long-term resilience. Some city-level climate action plans, such as the Mumbai Climate Action Plan (MCAP), do outline approaches to address UHI by expanding green cover. Yet, for families like Sonu's, who live in dense informal settlements, these plans often feel distant.

Extreme heat intensifies existing inequalities. While affordable interventions must reach those most at risk, it is also essential for policy measures to integrate social protection. This can look like cash transfers during heatwaves, robust worker safety standards, emergency cooling centers and outreach toward homeless populations.

Partnerships across government, civil society, private developers, researchers and local communities are essential to design and deliver effective measures. Decentralized, cross-sectoral collaboration can help ensure that policies respond to local realities.

Enable scalable actions

Reliable, granular data is also essential for designing and evaluating interventions. Heat-vulnerability mapping and monitoring of indoor temperature can help identify hotspots. Overlaying it with socioeconomic data, such as income and health, can identify particularly vulnerable populations for targeted interventions.

Formulating cooling guidelines tailored to building typologies, accompanied by beneficiary awareness and training of stakeholders involved in construction, are vital steps toward cooler buildings.

Sustained funding is equally critical. Climate adaptation funds, municipal green bonds, corporate social responsibility (CSR) programs and concessional loans can support retrofits, blue-green infrastructure and other cooling systems. Subsidies can help low-income communities afford improvements. Urban employment schemes could also be envisioned to support community-led cooling initiatives.

Towards Thermal Comfort for All

Extreme heat is reshaping how Indians live and work, but it impacts you differently based on where you live and work. Cooling efforts must serve to bridge this divide and not further exacerbate existing inequalities.

For people like Sonu, thermal comfort is a matter of health, dignity and survival. Combining proven solutions, such as passive cooling strategies, nature-based cooling, data-driven planning, and inclusive financing, will help India create urban environments that ensure thermal comfort for all and heat resilience that leaves no one behind.

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Climate-Resilient Urban Housing: Building Sustainable Communities

Anand Kumar Bolimera *

Housing stands as one of humanity's most fundamental needs. A decent home is the foundation upon which members of a family can build a better future for themselves. It serves as the cornerstone for improved health, education, socio-economic security, dignity, mental wellbeing and financial stability. Adequate housing helps families break free from cycles of vulnerability and enables them to build sustainable futures.

Today, the growing need for housing is further exacerbated by an unprecedented climate challenge. Climate change is no longer a distant concern but a present reality reshaping landscapes across South Asia. India experiences this through intensified floods, stronger cyclones, rising sea levels and severe heatwaves. The families Habitat India partners with are often among the most vulnerable to the effects of climate change. It can result in tragic outcomes for families, including damage or complete loss of their homes, which may expose them to other threats, such as food insecurity, disease and displacement.

Families move to cities in search of improved livelihoods and find housing in informal settlements where land tenure may be uncertain and access to services such as water, electricity and sanitation can be limited. These settlements frequently face challenges such as natural hazards like flooding, high population density, unaffordable rent and hostile environment. These factors underscore the need for well-rounded, inclusive approaches that support safe and climate-resilient housing, particularly as urbanisation continues to increase in areas susceptible to environmental risks.

The scale of these challenges demands innovative approaches, with one clear pathway emerging through resilient communities anchored by affordable, climate-resilient housing. Housing represents one of the most effective tools for families to strengthen themselves against multiple vulnerabilities, serving as a foundation for broader community resilience.

Housing For All: Government Leadership in Affordable Housing

The Government of India's Pradhan Mantri Awas Yojana (PMAY) has played a transformative role in advancing the country's vision of 'Housing for All,' enabling millions of families to realise the dream of owning a home. The success of PMAY reflects a proactive and adaptive strategy, providing both financial support and a clear implementation framework and continually evolving to meet diverse housing needs across India.

State governments have also demonstrated remarkable innovation in housing initiatives. For instance, The Odisha Liveable Habitat Mission (OLHM) also known as JAGA mission exemplifies state-led housing excellence, earning the World Habitat Award in 2019 from World Habitat and the United Nations-Habitat. The JAGA mission enabled tenure security access and linked families to PMAY-U housing subsidies, transforming 2,919 slums across 114 Urban Local Bodies into liveable neighbourhoods

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with improved drainage, street lighting, electricity and household toilets.[1]

Housing Support Services: Bridging the Gap

Habitat for Humanity India, working in partnership with the government and communities, has spent over four decades supporting families in vulnerable conditions to access safe, affordable and dignified housing. Through initiatives like Housing Support Services (HSS) and climate-resilient construction, models have been developed that are both adaptable and supportive of national priorities.

The substantial subsidy provided under PMAY enables underprivileged families to move closer to achieving homeownership. Yet, families at the lowest economic strata often require support to navigate technical aspects of construction and financial planning. Many lack direct experience with building processes and resources to bridge interim expenses before subsidy disbursement. While central and state contributions play a pivotal role, accessing remaining funds can present a barrier, as formal credit is limited and informal borrowing can prove costly.

In this context, Housing Support Services (HSS) empowers families by building financial awareness, providing technical guidance and linking them to reliable sources for bridging funds. By strengthening access to government schemes and facilitating every stage of home construction, HSS helps ensure that more families can complete safe, durable homes with confidence and independence.

In Puri district, Odisha, Habitat India implemented a successful Public-Private-People Partnership (P4), supporting over 500 families to complete the construction of homes. Collaborating with a housing finance corporation, the initiative provided accessible financing and addressed funding shortfalls. At the same time, tailored training and technical support enabled homeowners and masons to ensure quality, monitor progress and optimise use of available resources.

This comprehensive approach minimised unplanned expenses, improved the timely flow of government subsidy, and supported prompt project delivery. Project data shows that families using HSS support completed their homes within 180 days and 42% qualified for completion incentives as per PMAY guidelines.[2]

By aligning government subsidies with private finance and active community participation via the Public-Private-People Partnership (P4) model, Habitat India demonstrates that affordable housing finance can be promoted further after due consultation with the communities. In future, integrating corporate contributions under Corporate Social Responsibility (CSR) should be encouraged to meet the gap funding and offer additional timelines to complete such projects supported by CSR grants.

This will ensure that private sector resources complement public initiatives, amplifying impact and fostering inclusive growth. Technology-enabled real-time monitoring tools can also further promote transparency and accountability, enhancing the effectiveness of affordable housing programmes and supporting India's journey toward 'Housing for All.'

Building Climate-Resilient Homes

The Government of India's flagship Pradhan Mantri Awas Yojana (PMAY) is making significant progress towards fulfilling the Prime Minister's vision of Housing for All. At the same time, it is important to acknowledge that climate change can disproportionately affect vulnerable communities and potentially disrupt housing progress. This underscores the need to prioritise climate-resilient housing solutions.

Climate-resilient homes are designed to withstand local extreme weather conditions such as floods and heatwaves. Key features include raised plinths to protect against flooding, thermal insulation for improved comfort, solar panels to provide clean energy, rainwater harvesting systems, and efficient water and waste management. The use of locally sourced, environmentally friendly materials minimises energy consumption and reduces carbon footprints. For communities in disaster-prone areas like floodplains and vulnerable urban settlements, such homes offer a sustainable path to reduce damage and improve long-term resilience.

Demonstrating this approach, Habitat for Humanity India constructed three climate-resilient homes for families in Jatni and Khorda districts near Bhubaneswar. These homes, built with green construction technologies, earned

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the prestigious 'NEST GOLD' rating from the Indian Green Building Council. Features include elevated plinths, advanced insulation, solar energy systems, rainwater harvesting, and optimised water and waste management solutions. Additionally, Habitat India has built 15 climate-resilient homes in Pune district, Maharashtra, for the tribal community, incorporating similar sustainable design principles.

Building Resilient Communities Through Strategic Partnerships

Achieving resilient housing at scale relies on robust collaboration among government bodies, civil society, private sector and finance institutions. Habitat for Humanity India has made proactive efforts to bring diverse stakeholders together, fostering knowledge exchange and leveraging complementary expertise to advance inclusive, sustainable housing solutions.

In 2025, multi-stakeholder consultations in collaboration with the governments of Odisha and Andhra Pradesh brought together officials, technical experts, financial institutions and community partners. These collaborative forums focused on advancing climate-resilient, homeowner-driven construction within affordable housing schemes such as PMAY, integrating green building practices and finding solutions for funding, technical gaps and community engagement in both states.

Two clear priorities emerged from these efforts: first, equipping communities with targeted training for climate-resilient construction, particularly in high-risk areas; and second, institutionalising Housing Support Services to guide families at every stage, making owner-driven approaches more effective and inclusive. The State can play a proactive role by bringing various financial institutions, including public sector banks, to lend affordable credit to eligible households for the construction of homes.

The Path Forward: Building Resilient Urban Futures

As we observe World Habitat Day 2025, with the global theme of 'Urban Crisis Response', climate-resilient housing stands at the forefront of strengthening the social and economic fabric of vulnerable communities across India. By emphasising habitability, durability, affordability and inclusivity, these models empower low-income families to build secure futures and offer replicable pathways adaptable to diverse regions and states.

Nationwide scale-up of effective solutions like Housing Support Services and climate-resilient housing relies on sustained collaboration among governments, financial institutions, corporations, technical councils, civil society organisations and communities themselves. The journey ahead poses complex challenges: land tenure in densely populated areas, the need for creative financing solutions and ongoing community engagement. Yet, the Government's emphasis on 'Housing for All', pilot experiences across India show that when people, policy and partnerships unite, transformation becomes possible.

Disaster-resilient housing goes beyond structural safety. It represents dignity, security and opportunity ensuring that families are resilient and able to thrive even when faced with urban crises. Real climate resilience requires adaptation practices and locally sourced, appropriate materials that safeguard communities while reducing carbon footprints.

Habitat for Humanity India remains committed to convening stakeholders in shared partnership, responsibility and innovation to contribute to the national goal of housing for all. Through ongoing collaboration and community empowerment, every family can access safe, dignified shelter a foundation for prosperity as India shapes a sustainable urban future.

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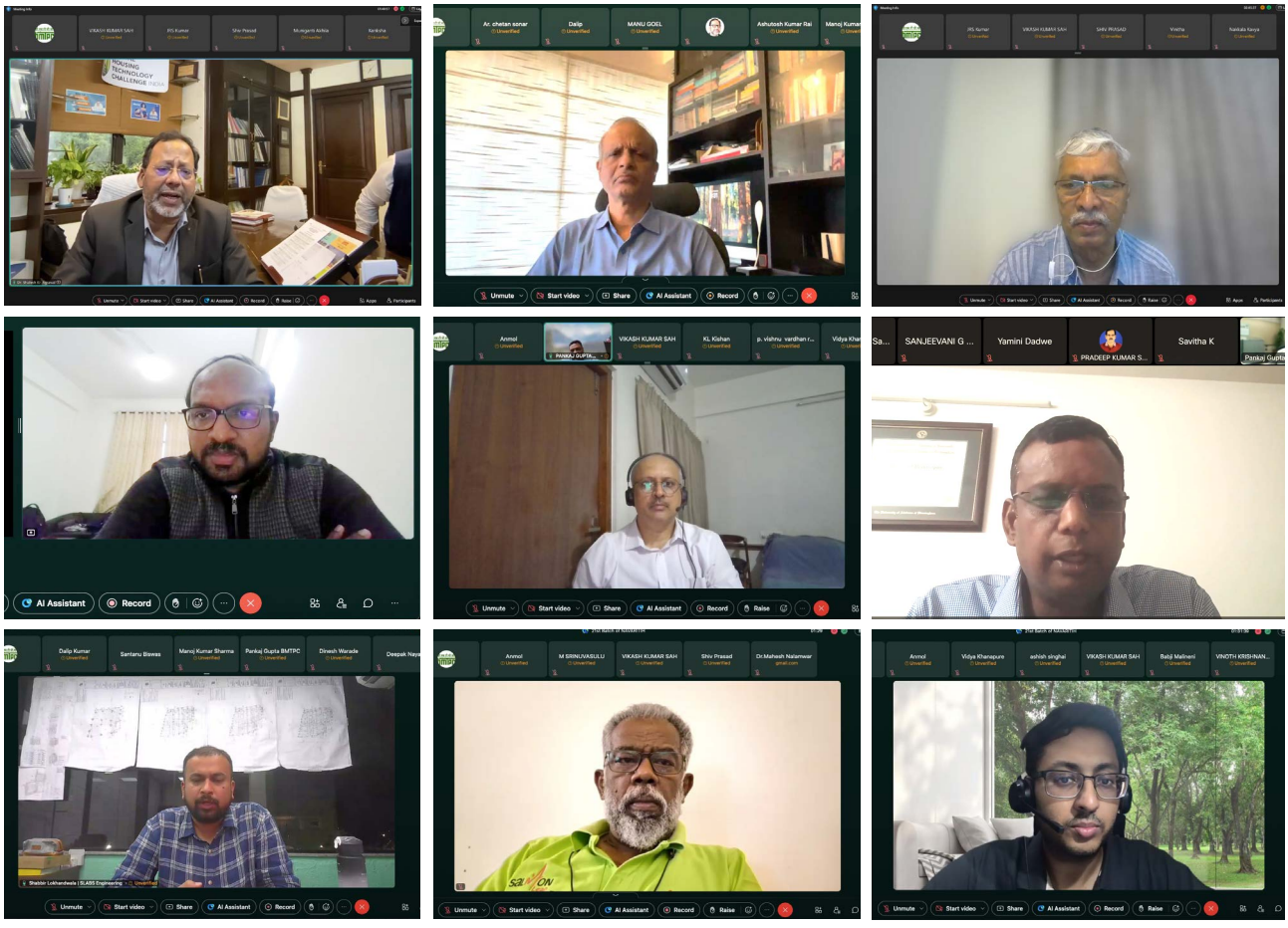
Partnered in 5th National Conference & Exhibition on Emerging Technologies in Construction & Infrastructure Sector and Sustainable Building Materials on July 18, 2025 at New Delhi

नवरीतिः NAVARITIH –
e-Certificate Course on Innovative Construction Technologies

The Ministry of Housing & Urban Affairs, Govt. of India in collaboration with School of Planning & Architecture (SPA), New Delhi and BMTPC, started NAVARITIH : Certificate Course on Innovative Construction Technologies to build capacities of engineers and architects including students in the area of industrialised building systems. It is of paramount importance that building professionals learn about the new and emerging building materials and technologies for housing and building construction. The objectives of the Certificate Course are to (a) Familiarize the professionals with the latest materials and technologies being used worldwide for housing, (b) Provide an awareness of the state of art of materials and technologies in terms of properties, specifications, performance, design and construction methodologies so that professionals can successfully employ these in their day to day practice and (c) Provide exposure to executed projects where such materials and technologies have been implemented.

The NAVARITIH Course was launched by Hon'ble Prime Minister through video conferencing in January 2021 during the foundation stone laying ceremony of six Light House Projects (LHPs) being constructed under Global Housing Technology Challenge - India – Pradhan Mantri Awas Yojana (Urban). Subsequently, first batch of NAVARITIH was inaugurated by then Secretary (HUA) in 2021.

The Course has received overwhelming response and so far in 21 batches conducted so far, 1278 participants comprising of civil engineers, architects, faculty & students from various engineering and architectural colleges have been successfully trained.



Resource Faculty delivering the lecture during the NAVARITIH Course

Ministry of Housing and Urban Affairs
Government of India

प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

School of Planning and Architecture, New Delhi

Building Materials & Technology Promotion Council, New Delhi

नवरीतिः (NAVARITIH)

Certificate e-Course on Innovative Construction Technologies

NAVARITIH : New, Affordable, Validated, Research Innovation Technologies for Indian Housing

An initiative of Ministry of Housing & Urban Affairs, Govt. of India
in collaboration with SPA, New Delhi & BMTPC

Objectives

(1) **Familiarise** with the latest materials and technologies being used worldwide for housing, (2) **Provide an awareness** of the state of art of materials and technologies in terms of properties, specifications, performance, design and construction methodologies, and (3) **Provide exposure** to executed projects where such materials and technologies have been implemented.

Target Group

Any person who has successfully completed and in possession of a minimum qualification of B.E. / B.Tech (Civil) or B.Arch. (or equivalent) or Diploma in Civil with 5 years' experience and final year students of Civil Engineering and Architecture shall be eligible to take up the Course.

Course Fee

Rs.2,500 per person (One-time, Non-refundable)

For Registration, please visit:
https://ict.bmtpc.org

e-Course on Vulnerability Atlas of India

An initiative of Ministry of Housing & Urban Affairs, Govt. of India
in collaboration with SPA, New Delhi & BMTPC

This unique e-Course offers...

- Identification of vulnerable areas with respect to natural hazards namely earthquakes, wind / cyclones, landslides, floods
- Help individuals in evaluation of multi-hazard profile of the region and incorporating them in DPRs, Design Basis and Tenders
- District-wise damage risk levels to the existing housing stock
- Basic understanding of earthquake, flood & cyclone resistant housing
- Disaster mitigation measures

Target Groups

- Individuals who wish to keep themselves abreast with knowledge about various hazards, vulnerability & disaster mitigation measures, in order to be better prepared.
- Students/Faculty/Practitioners/Researchers of Urban and Regional Planning, Civil Engineering and Architecture Colleges or any other allied disciplines
- Public/Private Professionals working in the area of housing & infrastructure sector e.g. Road, Rail, Aviation, Ports, etc.
- Defence/Central Armed Police Forces involved in Civil Engineering projects
- Officials of National/State Disaster Management Authorities
- Central/State/Local Government Officials
- Members of Consulting Organisations
- Members of Civil Society Organisations

COURSE FEE

Rs.1000/- per person
(Rs.500/- for Student)
(One-time, Non-refundable)

For Registration, please visit:
http://spa.ac.in or
https://ecourse.bmtpc.org

Signing of MoUs for dissemination and promotion of energy-efficient and sustainable materials & technologies

BMTPC has entered into MoUs with the following agencies for dissemination and promotion of energy-efficient and sustainable materials & technologies:

RMI Energy Solutions India Foundation, New Delhi

A MoU has been signed between BMTPC and RMI Energy Solutions India Foundation, New Delhi on December 7, 2024. The MOU envisages establishing a framework for long-term cooperation between BMTPC and RMI India Foundation to support low embodied carbon building material and construction technology initiatives at the national and sub-national levels in India.

Indian Institute of Sustainable Development (IISD), New Delhi

A MoU has been signed between BMTPC and Indian Institute of Sustainable Development (IISD), New Delhi on March 6, 2025. The MOU envisages to promote technical cooperation and partnership in sustainable construction, circular economy, and environmental sustainability and to collaborate on key areas such as (i) Technology & Research Cooperation, (ii) Academic Collaboration, (iii) Policy & Regulatory Innovation and (d) Training & Capacity building.

Development Alternatives (DA), New Delhi

A MoU has been signed between BMTPC and Development Alternatives (DA), New Delhi on March 12, 2025. The MOU envisages to work towards resilient cities and a sustainable built en-

Signing of MoU with RMI Energy Solutions India Foundation, New Delhi

Signing of MoU with Indian Institute of Sustainable Development (IISD), New Delhi

vironment through promotion of new building systems/ technologies, especially low-carbon, resource-efficient and circular solutions towards enhanced sustainable development. The MoU was exchanged with Ms. Zeenat Niazi, Senior Advisor, DA during the National Conference-cum-Expo on Innovative Building Materials & Construction Technologies on March 19-20, 2025.

National Institude of Technology Calicut (NITC)

A MoU has been signed between BMTPC and National Institute of Technology Calicut (NITC), on August 6, 2025. The MOU envisages to establish a framework for long-term cooperation to work towards climate resilience and disaster management of sustainable housing and to work together to identify solutions that enable the agenda of resilient cities and a sustainable built environment through the promotion of low-carbon and circular building materials and technologies.

The Habitat Emprise, New Delhi

A MoU has been signed between BMTPC and The Habitat Emprise, New Delhi on 10th September, 2025. The MOU is to collaborate and initiate research and undertake activities related to capacity building programmes and knowledge dissemination that can strengthen policy and research intervention in urban areas. The areas covered innovative building materials, technologies, and sustainable urban development, capacity-building and skill development for construction stakeholders, monitoring and evaluation of projects, collaboration in seminars and knowledge-sharing events, etc.

Besides, MoUs with MNIT, Jaipur and GreenTree Global, Noida are in pipeline.

Signing and Exchange of MoU with Development Alternatives, New Delhi

Signing of MoU with NIT Calicut

Signing of MoU with The Habitat Emprise, New Delhi

Demonstration Housing Projects – propagation of sustainable emerging construction systems under PMAY (U)

BMTPC is mandated to promote use of new / alternate building materials & technologies in housing through identification, evaluation, standardization, certification, capacity building, training and field level application by demonstration construction. Under Technology Sub-Mission of PMAY(U), MoHUA has taken an initiative to construct Demonstration Housing Project (DHP) through BMTPC using emerging construction systems shortlisted through GHTC-India & certified under PACS of BMTPC.

These DHPs are pilots which help build confidence and create enabling environment for the large scale adoption of such innovative materials & technologies suiting to different geo-climatic regions of the country, thus making housing more affordable and sustainable. So far, 14 DHPs have been undertaken with emerging construction systems shortlisted under GHTC-India (an initiative under Technology Sub-Mission of PMAY-U) and certified under Performance Appraisal Certification Scheme (PACS). Out of which, DHPs at (i) Nellore (Andhra Pradesh); (ii) Bhubaneswar (Odisha); (iii) Lucknow (Uttar Pradesh); (iv) Biharshariff (Bihar); (v) Hyderabad (Telangana); (vi) Panchkula (Haryana); (vii) Agartala (Tripura); (viii) Bhopal (Madhya Pradesh); (ix) Ahmedabad (Gujarat), (x) Tiruppur (Tamil Nadu), (xi) Ayodhya (Uttar Pradesh) and (xii) Bhalwal, Jammu, J&K were completed earlier. Recently, Demonstration Housing Project at Dimapur (Nagaland) has also been completed. The Demonstration Housing Project at Guwahati, Assam is at advanced stage and soon will be completed.

The construction of demonstration housing projects in different parts of the country aims to facilitate wide spread dissemination and adoption of both existing proven, emerging and sustainable building materials and technologies replacing conventional construction and create eco-system for mainstreaming such materials & technologies in the construction sector & adapt them as future technologies for construction. During the construction of demonstration houses, training to professionals, artisans & students is also being imparted.

DHP at Bhubaneshwar, Odisha using Prefabricated Sandwich Panel System - Reinforced Expanded Polystyrene sheet core with sprayed concrete

DHP at Biharshariff, Bihar using Structural Stay In Place Steel Formwork System

DHP at Lucknow, Uttar Pradesh using Stay in place EPS based double walled panel system with infill concrete

DHP at Hyderabad, Telengana using (i) Structural Stay In Place Steel Formwork System (16 houses) and (ii) Light Gauge Steel Structural System (16 houses)

DHP at Nellore, Andhra Pradesh using Glass Fibre Reinforced Gypsum Panel (GFRG) technology for houses and flyash blocks with filler slabs for community building

DHP at Panchkula, Haryana using Light Gauge Steel Structural System

DHP at Agartala, Tripura using Structural Stay In Place Steel Formwork System

DHP at Ahmedabad, Gujarat using Precast Concrete Construction System - Integrated Hybrid Solution-One

DHP at Bhopal, Madhya Pradesh using Stay In Place Formwork System - Insulating Concrete Forms (ICF)

DHP at Ayodhya, Uttar Pradesh using Light Gauge Steel Framework System (LGSF) with Cement Fibre board on both side of walls and infill of rock wool.

DHP at Tiruppur, Tamil Nadu using Precast Concrete Construction System –Precast Components Assembled at Site

DHP at Bhalwal, Jammu using Prefabricated Sandwich Panel System - EPS core Panel using Quikbuild Panels

DHP at Dimapur, Nagaland using EPS Cement Sandwich Panels with steel structure

DHP at Guwahati, Assam being constructed using Light Gauge Steel Framework System (LGSFS) with V-infill walls and Pre-engineered Building (PEB) steel structure

Performance Appraisal Certification Scheme (PACS)

Performance Appraisal Certification Scheme (PACS), being operated by BMTPC (vide Gazette Notification No. I-16011/5/99 H-II in the Gazette of India No. 49 dated December 4, 1999), is a third party voluntary scheme for providing Performance Appraisal Certificate (PAC) to manufacturers or installers of a product which includes building materials, products, components, elements, systems etc. after due process of assessment giving independent opinion about fitness of its intended use in building construction sector.

Since the Scheme is operated for the products/systems where no relevant Indian Standards are available, it is required to first work out the desired specifications for Performance Appraisal. For the items where no Indian codes are available, international practices are also being referred. In few cases the specifications recommended by the manufacturers have to be modified based on global practices to improve the quality and performance.

Various States/UTs, its Housing & Urban Development Departments, Housing Boards and other concerned departments are also promoting and using emerging technologies and materials for construction of mass housing in their States. As such PACS is proving to be an important tool for introduction of innovation in construction sector.

PACs Approved and Issued Till Date

Within the framework of power and functions of Technical Assessment Committee (TAC), Applications for appraisal of new building materials and construction technologies were received by BMTPC. Performance Criteria, based on National & International practices were framed in consultation with TAC members.

So far 20 meetings of TAC have been held and 88 PACs have been issued and out of these, 46 are emerging technologies/systems. The details of activities carried out recently under Performance Appraisal Certification Scheme (PACS) are highlighted below:

Approval of New PACs

PAC for the following four systems/products have been approved in the 20th meeting of TAC held on May 15, 2025.

1. Concrewall - Reinforced EPS Structural Panels (RESP)
2. Building Lifting Technique
3. Indowud Natural Fibre Composite Products
4. Insulated Sandwich Panel (Rigid Polyurethene/Polyisocyanurate Core)

The brief about these technologies are given hereunder:

1. Concrewall - Reinforced EPS Structural Panels (RESP) of M/s NBP Nirmaan Bharat Panels, MP

Concrewall is a building system based on factory produced reinforced Expanded Polystyrene (EPS) panels. These panels, consisting of undulated polystyrene sandwiched between electro-welded zinc-coated steel meshes, are inter-connected through cross connectors, thus creating three-dimensional hyper static reinforcement.

On-site, the panels are assembled and concrete is applied to form various structural elements, including vertical and horizontal walls, cladding, and internal walls. The use of galvanized steel and protective concrete layer ensures resistance to environmental factors, corrosion, fire, etc.

Salient features of Concrewall panel system include:

Concrewall - Reinforced EPS Structural Panels (RESP)

i. The chemically inert polystyrene used in the panel, helps it meet wide range of thermal efficiency requirements.

ii. The same type of panels allows the creation of vertical and horizontal structural elements, cladding, internal walls etc.

iii. The polystyrene used for the panels is Self-extinguishing in nature is, classified as Class 1 in fire safety. The material ceases to burn once the ignition source is removed.

2. Building Lifting Technique - M/s Krishan Lal & Sons, Haryana

Building lifting is a specialized engineering technique /process used to elevate the entire building structure for purpose such as addressing flooding issues, foundation repairs, etc. The process involves a thorough assessment of building condition, followed by detailed planning, preparatory works such as disconnection of utilities, installation of temporary supports etc., prior to lifting. The Lifting operation is executed with the help of series of jacks, uniformly placed under load bearing members, which are operated simultaneously to ensure even and stable elevation of the entire building structure. Once the structure reaches the pre-decided height, the foundation is modified/ rebuilt, and the building can be securely lowered onto the new base.

The benefits of the technique include the following:

i. Lifting and repairing a building is more cost effective than constructing a new one, when considering the expenses associated with demolition, debris removal, and new construction materials. Elevating & maintaining existing structures is more environment friendly also.

ii. Lifting a building allows for the repair/replacement of old, damaged, or inadequate foundations, enhancing the building's overall stability and safety.

iii. Lifting of building can correct issues related to soil subsidence, where the ground beneath a structure has settled unevenly, affecting structural stability.

iv. Elevating a building can improve site drainage, reducing the risk of water pooling and related damage around the foundation.

v. Lifting buildings in flood-prone areas can prevent significant damage from rising water levels.

Building Lifting Technique

3. Indowud Natural Fibre Composite Products - M/s Indowud NFC Pvt. Ltd, Chennai

Indowud Natural Fibre composite is an engineered wood alternative made primarily from agricultural fibers & polymers. It is designed to resemble wood in texture & appearance, and exhibits suitable performance for wide ranging applications.

It is manufactured primarily in the form of boards using a blend of natural fibers, PVC resin along with various fillers and additives such as lime stone, UV stabilizer, fire retardents, etc. to ensure required strength and durability. The product is useful for various applications such as exterior & interior cladding, panelling, furnishing, joinery and outdoor applications. The material can also be thermoformed and printed on.

The boards are available in the standard size of 8 feet x 4 feet (2440mm x 1220mm), with thickness options of 6mm, 8mm, 12mm, 15/16mm, 18mm, & 25mm. The boards have a rough surface on both sides, which enhances its usability. Further, the customized dimensions are also available of any size & thickness.

Salient features of the product include:

i. NFC boards are eco-friendly with no wood used. It uses agricultural residue-rice husk to the extent of 30% of total weight of the product that are often discarded or burned, thus transforming this waste into sustainable panels using advanced process. The agricultural residue used is more than 110PHR (Parts per hundred Resin).

Indowud Natural Fibre Composite Products

ii. The boards are recyclable, termite proof, resistant to pests / microorganisms, water & flame resistant and smoke suppressant.

iii. The product is resistant to weather conditions, moisture & temperature changes.

iv. It can be thermoformed, making it versatile in shaping and forming and useful for large number of applications including complex patterns.

v. Compatibility with numerous surface treatments as staining, printing, varnishing, painting, and overlaying with veneer or laminate.

vi. Suitable for CNC routing and can be easily handled with commonly available woodworking tools.

vii. Exhibits good screw-holding capacity, which can be further improved as per the requirement.

viii. The product is non-hazardous RoHS certified & EPD verified. It is free from formaldehyde, VOC emissions, lead and asbestos components.

ix. Possesses high thermal insulation (similar to wood) and decent acoustics properties.

4. Insulated Sandwich Panel (Rigid Polyurethene/ Polyisocyanurate Core) - M/s Suchi Foams Pvt. Ltd, Gujarat

The panels are manufactured as composite panels with an insulating layer of rigid core sandwiched between two outer metal sheets. These are modular building components, manufactured with varying facings, panel thicknesses and profiles. The outer layers of metal sheet facings are available with various surface coatings/finishing options including Pre-Painted Galvanized Steel (PPGL), Stainless Steel (SS) sheets, which offer weather resistance and rigidity to the panel. The rigid Polyurethane (PUR) or Polyisocyanurate (PIR) provides thermal insulation properties.

The panels can be used for walling, cladding & roofing applications in various types of buildings/ infrastructure works. The panels have advantages in terms of high-energy efficiency, light in weight, easy repair & replacement in case of damage etc. The design & engineering of structure using these panels is carried out based on applicable Indian Standards.

Insulated Sandwich Panel (Rigid Polyurethene/Polyisocyanurate Core)

PACs for Renewal

PACs for the following systems/ products have been renewed;

i. PUF Sandwich Panel with Pre Engineered Building Structure
ii. Bamboowood Products
iii. Modular Tunnel form
iv. Elastomeric Paintable Plaster
v. Strand Woven Bamboo Wood Flooring, Wall Panels & Door/ Window Frames
vi. Concrete 3D Printing Technology (C3DP)
vii. Factory Made Fast Track Modular Building System – INSTACON

Receipt of Applications for PACs

Applications for the following new products/systems have been received from the manufacturers for processing further for issue of PACs:

i. PEN Foundation (Pre –Engineered Foundation)
ii. CLEANFLO- Steelcare CRA (Corrosion Resistance Admixture)
iii. CLEANFLO- Inhibitor Solution Anti corrosive Coating of Reinforcement Bars
iv. Ecowall System
v. Politerm Blu- Thermal Insulation by Coated EPS Beads
vi. Structural Insulated Concrete Panels (EPS 3D Panels)
vii. GIB CoolMix – Light weight thermal insulation premix
viii. Glazed Iso Balls- Expanded Perlite

The above applications are being processed on the basis of data furnished by the firms, inspection of manufacturing plants at site of works and testing reports of samples of the products/ systems etc. before preparation of Performance Appraisal Certificates (PACs).

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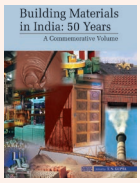

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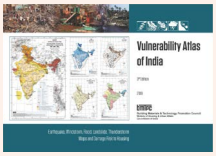

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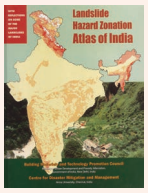

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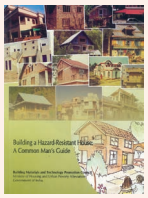

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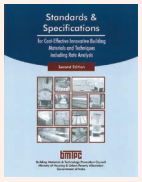

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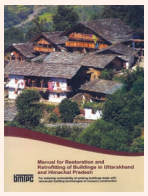

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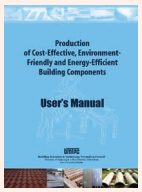

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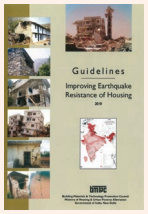

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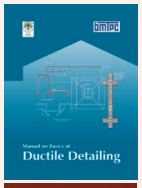

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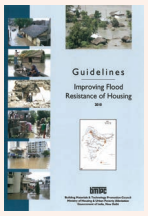

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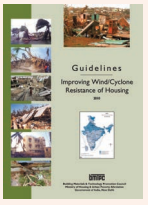

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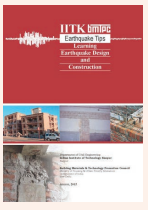

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6 October 2025

World Habitat Day

Urban crisis response

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Vision

"BMTPC to be world class knowledge and demonstration hub for providing solutions to all with special focus on common man in the area of sustainable building materials, appropriate construction technologies & systems including disaster resistant construction."

Mission

"To work towards a comprehensive and integrated approach for promotion and transfer of potential, cost-effective, environment-friendly, disaster resistant building materials and technologies including locally available materials from lab to land for sustainable development of housing."

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