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Seminar on

"Viksit Bharat 2047 and Infrastructure Development"

September 12-14, 2025
Nagpur

INDIAN BUILDINGS CONGRESS

PRELIMINARY PUBLICATION

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28th Annual Convention
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on

VIKSIT BHARAT 2047 and INFRASTRUCTURE DEVELOPMENT

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FOREWORD

It gives me immense pride to share this message at a time when our nation has embarked upon an extraordinary journey towards Viksit Bharat 2047. The vision of a developed India by the centenary of independence is not merely a dream, but a collective mission that calls for innovation, dedication, and synergy across all sectors—especially infrastructure development, which forms the backbone of progress.

Infrastructure is not just about building roads, bridges, and buildings—it is about creating systems that ensure connectivity, resilience, and sustainability for generations to come. The past decade has seen India transform its physical and digital infrastructure at an unprecedented pace, laying a strong foundation for the future. As we look ahead to 2047, the task before us is to build world-class infrastructure that is inclusive, environmentally responsible, and technologically advanced.

The Indian Buildings Congress (IBC), since its inception, has been at the forefront of knowledge-sharing, capacity building, and policy advocacy in the built environment sector. We recognize that timely completion, quality assurance, and the adoption of modern construction technologies are critical for realizing the vision of Viksit Bharat. Our emphasis must remain on sustainable materials, green buildings, smart urban planning, and integrated project management practices.

Equally important is the need to bridge regional and social disparities through infrastructure. Development must reach the remotest villages, ensuring housing for all, efficient transportation systems, renewable energy integration, and resilient public utilities. A truly developed India will be one where infrastructure empowers every citizen, regardless of geography or socio-economic background.

Capacity building of engineers, architects, planners, and project managers will play a defining role in this journey. IBC is committed to enhancing professional skills, disseminating best practices, and fostering collaborations with national and international institutions. By equipping our professionals with cutting-edge knowledge, we ensure that India's infrastructure stands as a model for the world.

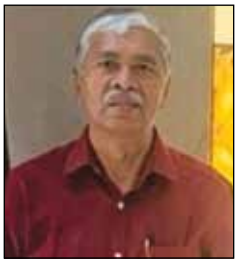
As we move towards 2047, the principles of sustainability, innovation, and inclusivity must guide every project undertaken. Smart cities, high-speed transportation networks, resilient rural infrastructure, and climate-conscious designs will be the hallmarks of the new India.

I am confident that with collective resolve and active participation of all stakeholders—government, industry, professionals, and citizens—our nation will not only achieve but surpass the goals of Viksit Bharat 2047. The Indian Buildings Congress pledges its full support in this national mission.

Let us together build the infrastructure of tomorrow, laying the strong foundations of a developed, self-reliant, and sustainable India.

(Er. C. Debnath)
President
Indian Buildings Congress (IBC) &
Fmr. President, IEI

PREFACE



Viksit Bharat 2047: A Vision for Infrastructure Development

As India is going to celebrate its 100th year of independence in 2047 as a developed country, infrastructure development is going to be a challenge for the engineers and a roadmap has to be prepared and implemented. This ambitious initiative aims to transform India's physical and social infrastructure, propelling the country towards sustainable economic growth and improved quality of life for its citizens. Hence, the topic of "Viksit Bharat 2047 & Infrastructure Development" selected for the Preliminary Publication to be released during 28th Annual Convention and the discussion during the National Seminar at Nagpur will prove a step forward in the direction. The document's emphasis on integrating technology, sustainability, and inclusivity in infrastructure planning is a positive step, reflecting a forward-thinking approach to nation-building.

The publication highlights the critical role of infrastructure development in driving economic progress, enhancing connectivity, and fostering social equity. By focusing on areas such as transportation, energy, water resources, and digital infrastructure, the government aims to create desired rate of India's growth. The vision includes developing smart cities, promoting renewable energy, and ensuring universal access to clean water and sanitation. These initiatives are expected to not only boost economic growth but also improve the overall well-being of the population, particularly in rural and underserved areas.

One of the key strengths of the Viksit Bharat 2047 vision is its emphasis on sustainable development, and environmental stewardship. As India continues to urbanize and industrialize, the need for green infrastructure and eco-friendly practices becomes increasingly important. The publication's focus on sustainable development aligns with global efforts to combat climate change and promote resource efficiency also. By adopting a holistic approach to infrastructure development, India can achieve its economic goals while minimizing its carbon footprint.

The success of Viksit Bharat 2047 will depend on effective implementation, stakeholder engagement, and continuous monitoring. It is essential for the government to work closely with the private sector, civil society, and local communities to ensure that the vision is translated into tangible outcomes. With its ambitious yet achievable goals, Viksit Bharat 2047 has the potential to transform India's infrastructure landscape and propel the country towards a brighter future. As India moves forward with this initiative, it is poised to become a model for sustainable development and economic growth.

(Dr. K.M. Soni)
Chairman, Technical Committee, IBC &
Former Additional Director General, CPWD

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GREEN AND BLUE INFRASTRUCTURE DEVELOPMENT IN URBAN AREAS: CHALLENGES & OPPORTUNITIES

Dr. Pawan Kumar*

Abstract

Green and Blue Infrastructure (GBI)are characterized as "Green-Blue Urban Grids" by embracing storm water management, climate adaptation and multifunctional green space. A typical blue-green infrastructure project may have several socio-economic and environmental benefits but its implementation in brown field city and creation of new GBI is a challenging task for ULBs. It is very important to bring functional, social, and economic changes through GBI developments in distant areas/districts in urban areas. In outlook of GBI, urban area may cherish as integrated system of 'socio-ecological' and 'socio-blue economy'. In socio-ecological context, planning and design of urban green spaces create socio-environmental integrity whereas socio-blue economy provides social and economic sustainability to the communities through various micro economical activities. In fact, GBI keep cities more sustainable with 'greater likelihood' and 'sufficient livelihood'.

INTRODUCTION

The Viksit Bharat@2047 has determinations for transforming India into a developed nation by 2047 AD at the centenary of its independence. The good governance as par changing global political scenarios and technological dynamism at par in changing world are vital components to bring transformation in development for making country as 'Viksit' and 'Great'. A critical component of this transformation is robust infrastructure development in terms of physical, digital, social, etc. Presently, green infrastructure and blue infrastructure are some of them which have wide impacts to reduce heat island effects, air pollution, water scarcity, etc. in urban areas and therefore their developments are more significant now-a-days.

The Green Infrastructure (GI) refers to nature-based solutions to address various environmental and social challenges whereas Blue Infrastructure (BI) refers to the network of water bodies and water management systems to provide environmental, social, and economic benefits by managing water which include both natural and engineered features. In other words, green infrastructure is considered a subset of "Sustainable and Resilient Infrastructure". It includes low-carbon infrastructure such as renewable energy infrastructure, public transport systems, etc. which contribute less emission, less carbon footprints and keep urban areas more clean and green.

*Town and Country Planning Organization, MoHUA, Govt. of India, New Delhi.

BLUE INFRASTRUCTURE AND GREEN INFRASTRUCTURE: AN INTEGRATED UNDERSTANDING

Blue Infrastructure and Green Infrastructure termed as Blue-Green Infrastructure (BGI) includes both "blue" elements such as rivers, lakes, ponds, wetlands, green roofs, etc. which bring about water flow & storage, whereas "green" features such as parks, urban forests, green walls, roof-top gardens, etc. help with infiltration, filtration, evaporation, transpiration, etc. Sometimes, Blue-Green Infrastructure is also characterized as "Green-Blue Urban Grids" by embracing storm water management, climate adaptation and multifunctional green space.

In broader sense, Blue-Green Infrastructure may also be considered as a component of sustainable urban drainage system which is integrated into urban planning to manage storm water. Therefore, sustainable urban drainage plan is always part and parcel of Master Plan of any town and city to avoid water logging, urban flooding, etc.

Further, Blue-Green Infrastructure is also associated with Gray Infrastructure. Gray Infrastructure is nothing but conventional storm water management system such as pipes, culverts, basins, etc. which are designed to collect and convey storm water away from urban areas. Table 1 describes comparative understanding of green infrastructure, blue infrastructure and gray infrastructure as shown below.

Table 1: Integrated Understanding of Green Infrastructure, Blue Infrastructure and Gray Infrastructure

S.N.	Infrastructure(s)	Understanding(s)	Example(s)
1.	Green Infrastructure	Natural Process by utilizing natural elements to manage storm water, improve water quality, reduce urban heat effects, etc.	Green Roofs: Roofs covered with green vegetation. Rain Gardens: Depressions in the landscape to collect and filter rainwater. Permeable Pavements: Pavements that allow water to pass through into the ground. Urban Forests: Trees and other vegetation in urban areas.
2.	Blue Infrastructure	It refers to all types of water bodies (surface and underground) available in urban areas. It is useful for water management and better micro climate at city level in urban areas.	Surface Water Bodies: Lakes, rivers, canals, etc. Underground Water Sources: Aquifers, wells, springs, artesian wells, hand-pump well, etc.
3.	Gray Infrastructure	It is traditional approach to manage storm water and removethe same from urban areas speedily. In other words, Gray infrastructure focuses on both traditional and engineered solutions used for managing storm water in urban areas.	Storm Water Management: Gutters, drains, pipes, detention basins, storm water sewer lines, etc. Wastewater Management: Sewage treatment plants, pipelines, etc.

Source: Collected from various sources and hence represent approximate information.

In fact, Gray infrastructure is crucial as it need technically design and proper maintenance otherwise may cause situations like water logging, urban flooding, etc. and damage water sources and qualities.

GREEN AND BLUE INFRASTRUCTURE DEVELOPMENT: GOVT. INITIATIVES

The Governments at different levels have initiated several programs and schemes for integrating green and blue infrastructure in urban development process. These initiatives aim to enhance urban resilience, improve water management, and create more livable & sustainable cities, etc. through enhancing greening areas and water surfaces. Table 2 describes Govt. initiatives for development of green and blue infrastructures.

Table 2: Govt. Initiatives for Green and Blue Infrastructure Development

S.N.	Initiatives	Govt. Agency	Description	Prominence
I.	Atal Mission for Rejuvenation and Urban Transformation (AMRUT)	MoHUA, Govt. of India.	It focused on providing basic amenities like water supply and sanitation, with an emphasis on green spaces and water body rejuvenation.	Green and Blue Infrastructure Development
II.	AMRUT 2.0	MoHUA, Govt. of India.	AMRUT 2.0 expands its scope to include water security, sewage management, and the rejuvenation of water bodies.	Green and Blue Infrastructure Development

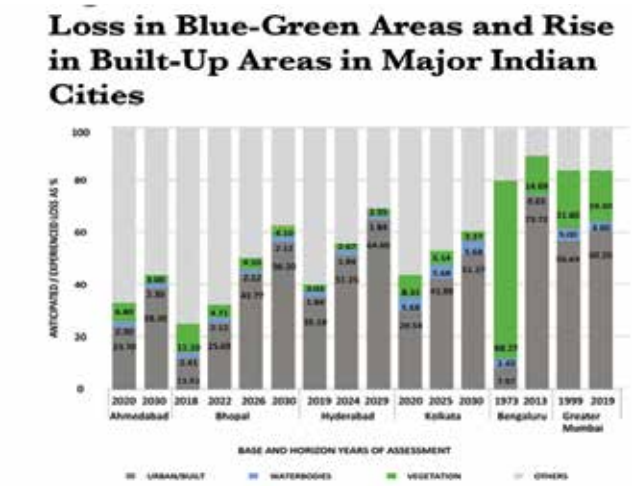
III.	Smart Cities Mission	MoHUA, Govt. of India.	Preserving and developing open spaces, parks, playgrounds, and recreational spaces in order to enhance the quality of life, reduce urban heat effects in urban areas.	Green Infrastructure Development
IV.	Nagar Van Yojana	Ministry of Environment, Forest and Climate Change, Govt. of India.	Nagar Van Yojana (NVY) scheme was launched in 2020, for creation of Nagar Vans in urban areas, which promotes urban forestry by involving local communities, NGOs, educational institutions, local bodies, etc. Nagar Van Yojana envisages creating 1000 Nagar Van / Nagar Vatika in Cities having Municipal Corporation/Municipal council/Municipality/Urban Local Bodies (ULBs) for providing wholesome healthy living environment for the residents and thus contributing to growth of clean, green, healthy and sustainable cities.	Urban Forests
V.	Green Highways (Plantation, Transplantation, Beautification &Maintenance) Policy, 2015	MoRTH	Promote greening and development eco-friendly National Highway corridors across the country with participation of farmers, private sector and government institutions including Forest Department. The main objective was to reduce the impact of air pollution and dust by planting trees and shrubs along the National Highways. They act as natural sink for air pollutants and arrest soil erosion at the embankment slopes.	Eco-friendly NH Corridors
VI.	"Scheme for Special Assistance to States for Capital Investment 2023-24" - Part-III (Urban Planning Reforms)	DoE, MoF	Strengthening Natural Ecosystem of Urban Areas through Urban Planning Aspects of the Reform: Policy interventions for urban water management and implementation of projects on ground for creation of Sponge Cities, including Urban Forests. Objectives of these reforms were to restore the city's capacity to absorb, infiltrate, store, purify, drain, and manage rainwater and regulate the water cycle. Master Plan for Sponge City is to be complemented with a Water Sensitive Urban Design (WSUD) document and enforcement mechanism. States is also to develop urban forests that can be defined as networks or systems of groups of trees, located in urban and peri-urban areas	i. Promotion of Sponge Cities for Sustainability (Conservation &Rejuvenation of Water bodies) ii.Promotion of Riverfront Development iii.Creation of Urban Forests

Source: Collected from various sources and hence represent approximate information

GREEN AND BLUE INFRASTRUCTURE DEVELOPMENT IN URBAN AREAS: MASTER PLAN APPROACH

A Master Plan of any town /city is prepared to guide planned development through various policies and development strategies to ensure coordinated and sustainable growth. In fact, it is a comprehensive and legal document guiding the city's development for a specific period, typically 20 years.

Green infrastructure and Blue infrastructure are important components and hence their developments are very crucial for livable and healthy city but several Indian cities have seen a decline in green and blue features due to rapid urbanization and haphazard development. One side, built up areas of the cities is increasing and other side green spaces, water bodies, etc. are shrinking. ORF has conducted a study which outputs illustrate loss of green and blue infrastructure in some of the selected Indian cities which is shown as Fig.1.



Source: ORF Occasional Paper Issue No. 317, May 2021

Many Indian cities have promoted green and blue infrastructure development through Master Plan provisions. The main aim is to enhance existing blue systems in the city through restoration and promote green development along them through planned strategies.

GREEN AND BLUE INFRASTRUCTURE DEVELOPMENT IN URBAN AREAS: CHALLENGES AND OPPORTUNITIES

It is well understood that a typical blue-green infrastructure project may have several socio-economic and environmental benefits. The different features such as rain gardens, bioswales, artificial/ natural wetlands, permeable pavements, etc. contribute water infiltrating, storing, treating storm water, etc. Further, vegetation and water bodies mitigate the urban heat island effects by providing shades and cooling through evapotranspiration, reducing energy consumption for cooling buildings, protecting from direct exposure to the Sun, etc. Some of the challenges and opportunities in development process of green and blue infrastructure are as follows:

- In brown field city, creation of new GBI is a challenging task for ULBs. A complete redevelopment of the areas requires proper space, adequate fund for maintenance, cleaning, disposal, etc. for better planning and design. It also needs to be integrated with existing grey infrastructure. In fact, it is a redevelopment of all three infrastructures i.e. green infrastructure, blue infrastructure and gray infrastructure for green, clean and healthy living environment in urban areas. .
- GBI and Climate Change Impacts are associated with each other. The effectiveness of GBI may be affected by climate change impacts such as increased frequency and intensity of extreme weather conditions. Contrarily, to mitigate climate change impacts, creation and restoration of green and blue infrastructure are essential. It is important to have sufficient GBI in urban areas to mitigate climate change impacts for more livable cities.
- Roles of Govt. policy, programs and financial assistance are very important in development of GBI. Further, public awareness and public demand for the same by the city residents is very crucial. It is very important to bring functional, social, and economic changes through such developments of infrastructure in remote and far away areas/districts in urban areas.
- In perspective of green and blue infrastructure, urban area may be determined as integrated system of socio-ecological and socio-blue economy. In socio-ecological context, planning and design of urban green spaces create socio-environmental integrity whereas soci0-blue economy provides social and economic sustainability to the communities through various activities of more economical activities. In fact, GBI keep cities more sustainable with 'greater likelihood and sufficient livelihood'.

CONCLUSION

According to the World Economic Forum, green and blue infrastructure is one of proactive adaptation for sustainable development, and enhanced quality of life for urban populations. The outcomes of research shows that 'green' and 'blue' infrastructure such as urban parks, wetlands, bioswales & water plazas, etc. mitigate physical risks and foster social cohesion critical to surviving and recovering from crises. In this context, it is imperative to understand that restoration & preservation of existing BGI and creation of new BGI are optimistic approach for sustainable, resilient and healthy urban environments in Indian cities. This approach integrates natural features such as parks, wetlands, urban forests and water bodies with built infrastructure which is very much desirable for addressing climate change, improving water management, and enhancing quality of life.

Green and Blue infrastructure (GBI) may be recognized as a tool for mitigating the impacts of urban heat islands, flooding, water scarcity, rapid storm water runoff, etc. Further, GBI offers improved public health and well-beings of the city residents through improved air &water quality, increased green spaces for recreation, cooling effects, etc. The need of the hour is to integrate GBI with existing infrastructure particularly with existing gray infrastructure. It requires holistic and effective approach to urban development and hence Govt. incentives and financial assistances are required through various schemes and programs for the same.

Presently, innovation and technological advancements are required for optimizing GBI design and implementation. The bioswales, rain gardens, etc. as landscape elements need to be created for capturing , filtering, and infiltrating storm water runoff along roadsides and in open spaces, parks, etc. Furthermore, blue-green action plan with innovative solutions like blue and blue-green roofs, painting of roof surfaces, walls to absorb rainwater, reduce storm water runoff, etc. need to be implemented by the Urban Local Bodies. Apart from green spaces, planting more trees, creating new urban forests, etc. it is also important to use cool pavements through using light-colored or reflective pavements to reduce heat absorption, moderate surface temperatures, etc. for urban cooling effects. It is a high time to restore and create wet lands for detention and filter rainwater, replenish groundwater and enhance biodiversity.

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NAGPUR REGION –AN EMERGING ALTERNATE SECOND CAPITAL OF INDIA

K.T. GURUMUKHI*

Abstract

In order to achieve the Vision 2047 set for the country by the Government the development will have to focus in all spheres of social, economic including the industrial development with advanced technologies, social and economic infrastructures like housing, health, education, research, national and international business centres, high order construction of roads, highways and superfast rail network, waterways, air ports and sea ports making India competitive. After independence the priority was on development of agriculture, construction of dams for irrigation, development of industrial estates, exploration minerals and development of industries based on mineral resources switching over to the British era.

Delhi was the capital of the country during British rule and continued to be the national capital till now. It is a fact that with the explosion of population growth of Delhi which had witnessed the highest growth rate have been facing innumerable problems and the basic services of infrastructure have been coming under severe stress despite all the efforts made by both central and state government. The issue of development of alternate second capital was raised in the Parliament by the honourable members and also the NCR Planning Board had been examining this for shifting of offices out of Delhi in Magnet towns/Cities but this could not make any headway.

After the lapse of 76 years, the problems of National Capital Delhi is well known and therefore, the new idea has been suggested to decentralize some of the government functions, offices, public sector undertakings, autonomous bodies, corporate office out of Delhi which have no direct role in Delhi. Thus the suggestions with strong justification has been made to give attention to the central part of India which will balance the development, generate employment benefitting the economic development to the people of the country.

INTRODUCTION

Delhi was the capital of undivided India and continued to be so, even after Independence. Hence, it was chosen by British and not by Indians. The British rulers chose Delhi for their own benefits and not for India, which is a multi-lingual and multi-cultural country. At the time of Independence, none thought of having a new location as politics was dominated by north at that time. Further, the economy of the country was not strong enough to even think of having a new location as the capital of India. Priorities were different and rightly so the first and the top most priority was to build the country. In addition; integrating the various princely states existing at that time to form a single Indian Union was a challenging task, which was ably and appreciably handled by Sardar Patel.

India was politically divided into states based on languages. English was the official language and it continued to be so till 1965. Regionalism was almost absent. The year 1965 sowed the seeds of Regionalism based on language when Hindi was declared as the official language. There was turmoil in the country which evoked wisdom in the minds of our rulers to continue English as official language in addition to Hindi. With the passage of time and the 1965 declaration made Regionalism to grow slowly and every state started adopting the state language as its official language. English was relegated to the background. It is a bitter truth that today the country is not as united as it was before 1965. The top priority of our rulers, therefore, has to be to inject in the minds of every Indian the sense of oneness with a broad vision of "Viksit Bharat". This, in the first place, calls for shifting the capital to the Centre of India, preferably near Nagpur as Delhi has reached the saturation point having many environment problems like pollution, congestions, earthquake, national security etc. There are many other steps that need to be taken for strengthening the unity of the country, but, shifting some of the functions of the capital to the Centre of India requires over-riding priority. A multi-lingual and multi-cultural country cannot afford to continue to have its capital with its Government offices, public sector offices and undertakings, corporate offices, research and training institutions which have no

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direct functions need not be at Delhi being in one corner of the country in the north. To preserve and strengthen the unity of the country, immediate need of the hour is to shift some of the functions as mentioned to the Central part of the country, preferably on the Nagpur - Wardha route and in the surrounding state capitals such as Bhopal, Raipur, Hyderabad and Sambhaji Nagar (formerly Aurangabad). There are many other valid and important reasons for shifting the capital functions and these are discussed below.

- The Ideal Location as Second Capital : Ideally centrally located with 0 mile stone, International Airport, going to be the Largest Cargo Hub in south Asia, Relatively socially a peaceful clean city being awarded 3 times by Times of India as best city to live in India. Entry in Guinness world records for highest density of Doctors in the city supporting health services to the people in the region.
- Centralised Connectivity – By Rail, Road and Air very well connected with all major cities of the country having common rail transport route between Nagpur – Wardha from where about 400 trains are passing through every day and biggest Cargo Hub.
- Safety and Security – As reported by Times of India in it's daily dated Oct. 16, 2017; Delhi being the worst megacity, with 26.5 million people; in the world defamed for sexual violence against women (rape, harassment and sexual attacks) in a poll survey conducted for 19 world's megacities (ranked by United nations during June and July 2017 by Thomson Reuters Foundation. The city is already known crudely as Rape Capital of India.
- Land Suitability and Availability – Flat surface of agricultural land all around Nagpur for further spatial expansion.
- Water Availability - Abundant water supply from Kanhan, Wardha and Wainganga rivers which can be interconnected for all purposes.
- Infrastructure – Social and Economic infrastructure is well developed with higher order Educational and Other Services including Health Care Facilities.
- Skilled Human Resources – Abundant supply of skilled and unskilled workforce.
- Indian Social and Multi-Cultural Influence – Citizens of Multiple Cultural background Societies from different parts of the country living peacefully in cosmopolitan life style.
- Peaceful Environment.
- Preferential Investment choice in Multi-sector Areas – Investors have preferential choices for Nagpur because of potential growth and proximity to Financial Capital Mumbai, Capital city Delhi besides very well connectivity to Raipur, Bhopal, Hyderabad, Chennai, Bangluru, Indore, Ahmedabad, Pune. Nagpur has International Marketing and Business Hub Potential too.
- Recreation and Tourism Potential in Wild Life having three National Parks around Nagpur, historical sites, forts, scenic areas, Centres of Spirituality, Natural Resources India, being a multi-lingual country, location of its Capital in the Centre of India is very important for national integration and inject in every mind the sense of Indian-ness. Everyone, starting from the mighty Himalayas in the north to Kanyakumari in the south, everybody will feel the oneness and will be proud to be an Indian. Regionalism can be eliminated. The feeling of hatred for English in the north and feeling of hatred for Hindi in the south will vanish and people may accept English as the official language, at least in the Central Government, since the Centre does not belong to any specific region and is common to all. Since the modern society is living in the Digital World and the whole world is inching towards becoming one in terms of economics, the need for every Indian to become an expert in English cannot be exaggerated. The states can follow the two-language formula, but, the Central Government should follow English only. Regionalism started growing in India only after 1965, when Hindi was declared as official language at Central level.
- Development can be evenly spread if the national second capital is located in the Centre of India. If electric light has to spread all over the room, the bulb has to be in the Centre of the room. This principle applies to 'development' also.
- Indian ports are nearer to Nagpur and this gives immense benefits to international trade taking place through sea-route.
- Nagpur seems to be less disease-prone. This can be due to its location. This has to be proved statistically and analyzed whether a link exists between its location and health of the people.
- South of Vindhyachal seems to be more inclined spiritually than north. A spiritual mind believes in egalitarianism, peace and so many

other virtues. This is why there is less law and order problem in southern states.

- Nagpur has almost unlimited land for expansion on all the sides.
- It has good climate for exploiting solar power. If the conversion of sea-water into potable water becomes cheap, Nagpur can reap the full benefits, as Nagpur does not have water scarcity.
- Nagpur is free from natural disasters and also does not fall into seismic zone.
- Nagpur is almost at equal distance from the super metros of Delhi, Chennai, Kolkata and Mumbai.
- Nearness to abundant sources of minerals required for main industries like iron and steel, cement, power, aluminum etc. etc.

INDIA'S URBANISATION CHALLENGES

The lopsided urbanisation with induced growth of large cities ignoring industrialisation of tier 2 and tier 3 cities or strong economic base in the rural set up is likely to lead a chaotic situation in the country in future. Rather, urbanisation has become mainly a product of demographic explosion with rural – urban migration, growth of slums in almost all cities, inequalities with rising gap between rich and the poor, deteriorating quality of life and urban decay. It is interesting to note that in the next 25/30 years, about 50 % population will be living in urban centres. India's urbanisation is involutedly worrisome due to migration of illiterate, unskilled labour from rural areas witnessing urban misery and rural poverty to become increasingly apparent considering the projected population of India to be 1.8 billion by 2050 and 2.8 billion by 2100 out of 10.50 billion population of the world. The rural areas will not be able to support projected rural population in agriculture sector and other related allied activity areas there by, they will be migrating forcibly to urban centres. The future urbanisation challenges will have to be tackled in a planned manner, while balancing economic activities with population distribution all over the country by the Central and State Governments in accordance to United Nations Agenda for sustainable and resilient urban future through inclusive economic growth, productive employment, decent work for all, making cities and human settlements inclusive, safe, resilient and sustainable promoting peaceful and inclusive societies, provide access to justice for all and build effective, accountable and inclusive institutions by the country being signatory. The Prime Minister of India has rightly mentioned in his address at Davos and invited various country heads for investment in India while counting the progress made by the country in the past 20 years. He impressed upon them on the basic concept of "Vasudhaiva Kutumbkam" and advocating for investment in India being the best choice in many ways and to join hands for better future of his countrymen. Managing urban growth has become one of the most important challenges to all of us which will have to be dealt with determination in a time bound manner.

OPTIONS FOR DECENTRALIZATION OF NATIONAL CAPITAL – DELHI

India has capacity to absorb projected population by dispersal of economic development along the road and rail corridors and create employment opportunities both for urban and rural population through spatial district development plans as per 73rd and 74th Constitutional Amendment Act, 1992 within the National and State Urban Development Strategy. The functions of National Capital and all Central Government major establishments including international establishments are bound to be in Delhi besides the setup of the State Government i.e. NCT Delhi and it's establishments. The mandatory functions of the Central Government in accordance with the Constitution of India will have to be in the National Capital but the Departments, Public Sector Offices, Autonomous Bodies Research and Training Institutions, Corporate Offices which have no direct role in governance and have budgetary allocations can operate from anywhere in the country. Therefore, it will be more justifiable to shift them out of Delhi. This process of change will have multiplier effect to balance the governance of the country in the long run. There is a need to develop a second capital to share the burden of governance locating it somewhere at the centre of the country which will be backed by urban infrastructure, availability of land, skilled manpower etc. etc. It is suggested that:

- Shifting of Central Government Head Offices including their Research and Training Centres having its independent budgetary allocations; since these are not directly connected with National Capital functions. These offices should have their Liaison Offices with skeleton staff and Guest Houses at Delhi.
- Shifting of all Public Sector Offices, Autonomous Bodies and Corporate Offices to other cities and suitable locations according to justifications.

- Decentralising Supreme Court establishments at zonal level to impart justice instead of making every litigant to come to Delhi for seeking justice.
- Promoting States to set up International Business and Trade Centres to facilitate Entrepreneurs and Business Communities, promote FDI and marketing centres.

CONCLUSION

With the above mentioned policy decisions by the Government of India and the State Governments; it will have a multiplier effect in many ways namely:

1) The National Capital of India will be comparable with any world class city recognised as the capital of the largest democracy of the world and also international metropolis.

2) Population of National Capital – Delhi will be contained and the city's growth will be slowed down drastically as the existing population will be moving out due to decentralisation exercise.

3) There will sea change in the city climate, reduced pollution level, reduction in number of vehicles and will help to clean the air.

4) Informal sector will be greatly reduced and so the slum population including jhuggies or slum clusters along with a big jump in the city personality.

5) It will be possible for the city Government to maintain world class standards in social and physical infrastructure provisions to its citizens.

6) The second capital – Nagpur will be able to absorb additional population because of its resources and availability of land for city expansion and accommodate work centres, social and physical infrastructure etc.

7) All other cities around Nagpur such as Hyderabad, Bhopal, Raipur and Sambhaji Nagar or Jalgaon can be identified for shifting of selected Corporate Offices, Autonomous Bodies, Research and Training Centres and other services to be shifted from Delhi or newly developed establishments will be able to absorb more economic activities and create / generate employment opportunities, share prosperity of the country by the people.

8) Decentralisation of offices and its subsidiaries will have a multiplier effect in balancing population distribution at national level. It will help in the development of physical and social infrastructure in the long run and extend wellness in the hinterland.

9) The people of India will be able to enjoy equal opportunities and share the fruits of a powerful country through their participation in 'Make in India' role leading towards Viksit Bharat.

10) Finally the people of India will be able to play their responsible role in integration and feel proud to be an Indian when every citizen is ripping the fruits of prosperity.

Right time for the National Government is to call for a brain storming session to debate on this issue and arrive at a decision for the future of the Vibrant Nation for its sustainable economic growth in national interest and also to aim at Viksit Bharat.

Note: Views expressed in this note are of the Author which does not bind any Government or Organisation.

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THE ROLE OF BULK WASTE GENERATORS IN DELHI'S SOLID WASTE MANAGEMENT: LEGAL FRAMEWORK AND IMPLEMENTATION GAP

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Abstract

This paper examines how Delhi's bulk waste generators (BWGs) including residential societies, institutions, and commercial establishments contribute to municipal solid waste generation and management. Focusing on the legal provisions under the Solid Waste Management Rules, 2016, and Delhi's local legislations, it explores the regulatory obligations assigned to BWGs for source segregation, storage, and handover of waste to authorized systems. Through a review of secondary reports, government audits, field surveys, and case studies, the analysis highlights an implementation gap between policies and actual practices. Key barriers include lack of enforcement, limited awareness, inadequate infrastructure at generator premises, and coordination challenges among stakeholders. The paper assesses emerging initiatives, such as extended producer responsibility (EPR) pilots and digitization efforts, and offers policy recommendations to improve compliance and participation by BWGs. Strengthening municipal monitoring, incentivizing segregation compliance, and promoting public private partnerships are central to bridging the policy–practice divide. The study concludes that addressing the BWG role is critical to reducing Delhi's land filled waste volume and realizing integrated, sustainable solid waste management.

INTRODUCTION

Delhi generates more than13,000 tons of municipal solid waste daily. Bulk waste generators (BWGs) such as large housing complexes, educational institutions, hospitals, commercial malls, and industrial units contribute disproportionately to this volume and offer strategic opportunities for improved waste segregation and recycling at source. SWM Rules (2016) and Delhi Municipal Corporation Act, 1957 assign clear duties to BWGs but effective implementation remains challenging. This paper investigates the legal framework governing BWGs in Delhi, the existing implementation gaps, and potential solutions to ensure compliance and improved environmental outcomes.

Research Questions:

1. What legal obligations exist for BWGs under national and Delhi-level legislation?
2. How well are these obligations implemented in actual practice?
3. What are the barriers to compliance, and how can they be addressed?

Methodology: A qualitative approach: review of legislation, municipal guidelines, government audits, media, various reports, and interviews with waste-management stakeholders.

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LEGAL AND POLICY FRAMEWORK

National Level: SWM Rules, 2016

- Section 7: Responsibilities of waste generators including BWGs with green, blue, and red bin segregation.
- Rule 7(1) (a): Mandatory segregation for "bulk waste generators."
- Rule 13: Authorizes municipalities to implement SWM systems and enforce compliance.
- Rule 14: Licensing of waste pickers and authorized service providers.
- Rule 15: User fees and segregation incentives.

Extended Producer Responsibility (EPR)

- Introduces obligation for producers, brand-owners, and e-commerce entities etc to finance waste collection and recycling of packaging waste.
- BWGs are secondary stakeholders as beneficiaries of collection systems.

Delhi-Specific Legislation

- Delhi Municipal Corporation Act, 1957 (as

amended) empowers civic bodies to charge SWM fee.

- Delhi's Annual Action Plans include BWG modules aiming at segregation drives in societies and institutions.
- Municipal bye-laws in South, North, and East Delhi Municipal Corporations lay down specific fines.
- The Solid Waste Management Bylaws, 2017 notified by the Municipal Corporation of Delhi (MCD) on January 15, 2018operationalize the national Solid Waste Management Rules, 2016 in Delhi's context. They specifically address Bulk Waste Generators (BWGs) entities producing more than 100 kg of municipal solid waste per day by expanding, detailing, and enforcing duties established at the national level.

➢ **Definition of "Bulk Waste Generator**

The solid waste by laws were formally notified on January 15, 2018, applying across all civic bodies in Delhi including MCD, NDMC, and Delhi Cantonment Board. These by laws operationalize SWM Rules 2016 at the local level for BWGs within designated municipal jurisdictions. In alignment with SWM Rules 2016, a Bulk Waste Generator is any entity generating over 100 kg of municipal solid waste per day, or notified by local authorities even if generation is below the threshold. Typical BWGs include large residential societies, educational institutions, hospitals, hotels, markets, places of worship, and sports complexes etc.

➢ **Process in BWGs**

a. Segregation and Storage Duties

All BWGs must segregate waste into three categories at the point of generation: biodegradable (wet), non-biodegradable (dry), and domestic hazardous waste, storing it in covered, separate containers.

b. In-situ Processing

BWGs are required to process wet waste on-site, either through composting, biogas, or similar decentralized systems, wherever feasible. Horticultural waste must also be composted in situ or disposed as instructed if space is limited

c. Authorized Handover of Dry & Hazardous Waste

Segregated dry recyclables and domestic hazardous wastes must be handed over exclusively to authorized MCD collectors or licensed agencies. Mixed or inappropriate disposal is strictly prohibited.

d. Registration, Verification & De-listing

Delhi ULBs must:

- Identify and notify potential BWGs via public notices and personal communications.
- Accept self-declaration from entities claiming below 100 kg/day.
- Conduct verification visits on at least three occasions (Sunday, preceding day, one working day). If self-declaration is false, penalties are charged retroactively up to 100% surcharge plus user fees
- The de-listing process requires consistent waste below threshold in at least two verifications, with the third not exceeding 110 kg/day

e. User Charges & Penalties

By laws authorize ULBs to levy user charges for waste processing services, plus surcharges for delays (e.g. 10%). Schedule II of the SWM By Laws outlines fines for non-compliance:

- Residential BWGs: Approx. ₹200 per infraction
- Non-residential: ₹500–₹10,000
- Major violations: up to ₹1,00,000 (e.g. large events, improper packaging disposal)

f. Institutional Oversight & Support

Each ULB is mandated to establish a Bulk Waste Generator Monitoring Cell, led by a senior officer, to conduct regular inspections using standardized checklists and provide technical but no financial assistance to BWGs for compliance (vendor lists, processing options, composting).

Institutional Framework

- Coordination between urban local bodies (ULBs), Delhi state government, Delhi pollution control committee (DPCC), and private service providers.
- Role clarity is often blurred and in general undermining accountability.

Key Provisions for BWGs in Delhi SWM Bylaws 2017

a. Mandatory Registration of BWGs

- All entities generating over 100 kg/day, e.g. large housing societies, hotels, markets, institutions etc must register with MCD, now facilitated via the MCD 311 mobile app on Android and iOS.
- A dedicated inspection team monitors and enforces compliance.

b. Register→Segregate →Process →Handover

BWGs must:

- Segregate waste at source into wet (biodegradable), dry (recyclable), and domestic hazardous categories.
- Process wet waste in situ (e.g. composting or biogas) on premises wherever feasible.
- Hand over segregated dry and residual waste to MCD authorized collectors.
- Wrap sanitary wastes securely and dispose separately.

c. Identification & Verification Protocol

- MCD issues public notices and individual communications to identified BWGs and collects self-declarations from entities claiming under 100 kg/day.
- Verification occurs over multiple visits across varying days; false claims lead to backdated user charges + 100% penalty. Entities can apply for de-listing after sustained low waste generation.

d. User Charges & Penalties

As per the Schedule II of the SWM By Laws:-

- The bylaws empower ULBs to impose user charges based on estimated or measured generation volumes. Late payments attract a 10% surcharge.
- Penalties for non compliance—such as failing segregation, burning, or improper disposal are outlined:
    - Residential BWGs: ₹200 per default
    - Non residential: ₹500–10,000 depending on activity
    - Major violations: ₹1,00,000 (e.g. event-related breaches, packaging rule violations).

e. Monitoring & Support by MCD

- ULBs must establish a BWG Monitoring Cell, conduct regular inspections using checklists, and support technically not financially through handholding, vendor lists, and composting options.

Status of Implementation in Delhi

- As per the survey and stakeholders interviews only less than 30% of identified BWGs in Delhi are reportedly complying with required norms like on site processing and segregation. Out of approximately 3100 registered BWGs, only around 900 were found to process wet waste on-site as mandated.
- In February 2025, MCD made registration mandatory via the 311 app and set up dedicated oversight under SWM Bylaws 2017, aligning with Supreme Court directives.
- As part of improved oversight, the city has deployed online monitoring modules, plans to empanel service providers, and proposes property tax incentives for compliance and zero-waste certification.

Legal vs. Practice: Implementation Gap

Provision in Bylaws 2017	Ground Reality
Mandatory registration via MCD 311 app	Many BWGs not yet registered; monitoring only recently enabled
Segregation 3 streams + on site processing	Less than 30% compliance; poor records of composting or dry waste handover
Issuance of fines and enforcement by byelaws	Few penalties actually recovered; enforcement largely symbolic
Verification of self-declarations and delisting protocols	Processes defined, but scaling uneven and resource intensive
Dedicated Monitoring Cell and capacity building support to BWGs	Technical support limited; ULB infrastructure and follow through is there but more attention and enforcement is needed

ROLE AND RESPONSIBILITIES OF BWGs

- Source segregation: Provision of color-coded bins and ensuring residents/orgs segregate.
- Bulk waste storage: Setting up storage rooms or composting units.
- Handover to authorized collectors: Must connect to local MRFs, waste-pickers, or municipal services.
- Payment of user charges: Funds municipal operations and infrastructure.
- Reporting: Maintain records of waste generated, segregated, and handed over; required under SWM Rules.
- Updating the Daily Report: Online updating of the records of waste generated, segregated, and handed over; through the 311 app of MCD.

IMPLEMENTATION GAP IN DELHI

On-Ground Reality

a. Compliance Rate

As per an MCD sanitation report (Sept 2024), Delhi has identified about 3,000 BWGs, yet only about 900 (under 30%) are actively carrying out on-site wet waste composting, as mandated

b. Awareness Campaigns

Following Supreme Court directives in April 2025, MCD has launched city-wide awareness drives via the MCD 311 app, media campaigns, grievance mechanisms, and stakeholder meetings (over 431 held). Penalties collected via challans have already reached around ₹9.6 lakh

c. Digital Registration & Monitoring

Registration through the MCD 311 app has been made compulsory from February 2025, complemented by a dedicated inspection team to audit BWGs. There are now plans for strengthen the inspection teams and empanelling private service providers in future to support BWGs in compliance

d. Institutional Barriers

Field-level research by non-profits highlights systemic gaps: weak enforcement, poor data tracking, lack of comprehensive BWG inventories, and inadequate sensitivity of the BWGs

e. Incentives and Zero Waste Certification

To encourage compliance, MCD is offering property tax rebates and zero waste certification to societies that achieve high segregation and on-site treatment standards. By 2025 26, they aim to certify an additional 200 such colonies

f. Summary

Provision under SWM Bylaws 2017	Current Implementation Status
Mandatory BWG registration via MCD 311	Registration mandated since Feb 2025; monitoring teams in place
Source segregation (wet, dry, hazardous)	Compliance < 30%; low segregation adherence
On-site wet waste processing	Only ~900 BWGs (out of ~3,100) comply with composting
Penalties for non-compliance	₹9.6 lakh collected; fines under utilised
Verification and de-listing processes	Operational but resource-intensive; efficacy varies
ULB Monitoring Cells & technical support	Cells exist; support available; enforcement inconsistent
Awareness campaigns and app publicity	Rolled out under SC directive via MCD 311 app and multi channel media
Incentives – tax rebates and zero waste status	Active; more colonies targeted by 2026

- Surveys show less than 30% of BWGs comply with segregation mandates.
- DPRs from MCD highlight being in the initial stage, so low enforcement and few penalty cases.

Barriers to Implementation

- Low Awareness and Training: Residents and staff often uninformed about segregation protocols.
- Insufficient Infrastructure: Societies lack

compost pits, dry waste storage, or biogas units.

- Weak Enforcement: ULBs rarely collect fine; one-off drives are ad-hoc.
- Coordination Failures: Delays in waste collection, private vendor unreliability, disputes on fees.
- Economic Constraints: BWGs unwilling to invest in segregation units without observable benefits.

Case Study Highlights

- Housing complexes in Dwarka and Chhatarpur deployed active segregation programs; their key success factors included outsourcing to waste management firms combined with resident awareness drives.
- Educational institutions like Delhi University's North Campus implemented composting, yet reported low dry waste handover to recyclers.

EMERGING INTERVENTIONS

- Digitized SWM Apps: Delhi's "Delhi Swachh" app allows BWGs to raise bin bate requests and monitor compliance.
- EPR Pilot Initiatives: Trials covering packaging collection in malls and societies under EPR mandate.
- Incentives and Penalties: ULBs offer rebates for active segregation and impose modest fines.

DISCUSSION

- Structural gap: Even with legal clarity, Delhi's regulatory enforcement remains weak and still is in nascent stage.
- Motivational deficit: BWGs see SWM as compliance burden without direct benefits; few waste to money channels exist.
- Private sector inclusion: Outsourcing to specialized firms shows promise, but scale-up depends on transparent contracts and consistent monitoring.
- Policy synergy: Alignment of EPR goals with BWG incentives can create shared responsibility and sustainable funding.

FINDINGS & RECOMMENDATIONS

Based on the findings of this research, it is evident that a multi-pronged approach is necessary to bridge the implementation gap in Delhi's solid waste management (SWM) framework, especially with regard to the obligations and performance of Bulk Waste Generators (BWGs). The following recommendations are proposed to enhance regulatory compliance, institutional efficiency, and environmental outcomes:

i. Strengthening Regulatory Enforcement

- Municipal authorities must operationalize dedicated Bulk Waste Monitoring Cells with the authority to not only inspect, issue penalties, and publish compliance reports.
- A structured compliance dashboard with GIS tagging and real-time waste tracking (e.g., through the MCD 311 app) should be used to monitor registered BWGs but also to guide the BWGs about the benefits and necessity along with the legal provisions.
- Uniform enforcement across all zones of Delhi should be ensured through the standardization of challan mechanisms, frequent inspections, and the imposition of timely penalties under the SWM Bylaws, 2017.

ii. Improving Registration and Identification

- A comprehensive survey of potential BWGs should be conducted quarterly, with mandatory re-registration and waste audits for existing entities.
- Third-party verification agencies may be empanelled to assist in data collection, reporting, and awareness campaigns.

iii. Enhancing Infrastructure and Technical Support

- MCD should facilitate the setup of on-site composting units and Material Recovery Facilities (MRFs) through capital subsidies or public-private partnerships.
- Housing societies and institutions should be incentivized to procure organic waste converters (OWCs), biogas plants, and secure dry waste storage areas.
- A panel of certified private waste management

vendors should be maintained by municipal bodies for BWGs to engage directly.

iv. Fiscal Incentives and Disincentives

- BWGs achieving 100% segregation and on-site wet waste processing should be rewarded through property tax rebates, waste collection fee discounts, or public recognition (e.g., "Zero Waste Society" certification).
- Escalating penalties for repeated non-compliance should be enforced, alongside disqualification from municipal services where violations persist.

v. Capacity Building and Behavioural Change

- Regular training sessions must be held for resident welfare associations (RWAs), housekeeping staff, and waste handlers at BWG premises.
- Customized IEC (Information, Education, Communication) materials in Hindi and English should be distributed, with focus on three-bin segregation, composting methods, and responsible disposal of hazardous waste.
- Competitions and green rating systems may be introduced to motivate participation.

vi. Policy Integration and Institutional Coordination

- A city-wide BWG coordination task force should be established involving MCD, DPCC, RWAs, NGOs, and private service providers to streamline interventions and resolve bottlenecks.
- EPR (Extended Producer Responsibility) mechanisms should be leveraged to co-fund BWG waste collection and processing infrastructure, particularly for packaging and plastic waste.

vii. Transparency and Public Accountability

- A public BWG compliance registry should be published quarterly by MCD, listing registered generators and their performance status.
- Grievance redressal mechanisms (through online portals or mobile apps) should be strengthened to allow residents to report violations or request waste management services.
- All the information , guidelines and reports shall be posted on a dedicated page on the MCD portal

By implementing the above recommendations, Delhi can substantially improve the role of BWGs in solid waste management and move toward a more decentralized, circular, and sustainable urban waste ecosystem. The success of such interventions will depend on the institutional capacity, and active participation of all stakeholders i.e. public and private alike.

CONCLUSION

Despite being legally obligated, a large number of BWGs in Delhi have not registered with the municipal authorities or adopted in-situ composting and segregation protocols. Data reveals that less than 30% of the identified BWGs in Delhi comply fully with segregation and on-site waste treatment norms. The reasons for non-compliance are multifaceted dranging from low awareness and technical constraints to weak municipal enforcement, inadequate penalties, and absence of sustained behavioural change interventions. Verification mechanisms and enforcement tools, though outlined in the bylaws, remain underutilized or inconsistently applied across jurisdictions.

In conclusion, while the legal framework governing BWGs in Delhi is robust and well-defined, the implementation deficit undermines the larger goals of sustainable solid waste management. Bridging this gap requires a multi-pronged strategy involving improved enforcement, capacity building, fiscal incentives, and community participation. Municipal bodies must act as enablers not just regulators by investing in monitoring infrastructure, offering on-ground support to BWGs, and fostering a culture of waste responsibility. Only then can the vision of decentralized, accountable, and environmentally sound solid waste management in Delhi be realized.

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VIKSIT BHARAT@ 2047: VISION, CHALLENGES AND ROADMAP FOR INFRASTRUCTURE DEVELOPMENT

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Abstract

The Government of India has announced "Viksit Bharat 2047" emphasizing the need of India becoming a developed nation by 2047. For a developed nation, economic growth and economic development are the key factors however to bring the economic growth of the country with economic development of its citizens to the level of developed nations, there are many challenges for which a roadmap needs to be prepared at Government of India level involving State Governments if it wants India to be developed as "Viksit Bharat" by 2047. For a developed nation, safe and quality infrastructure is going to be a prime objective.

India faces many natural and man-made disasters, causing massive losses of the resources, lives and property. Earthquakes, cyclones, flash floods, droughts, landslides, avalanches, cloud bursts, poor drainage systems, forest and building fires, road, train and air accidents, and collapse of buildings, bridges and highways lead to massive economic loss. If the same is not controlled, goal of "Viksit Bharat" cannot be achieved. Losses in infrastructure projects also occur due to time over-run, poor quality work, poor maintenance, and unauthorised unsustainable development. Therefore, India has to minimize such losses to a negligible level, if not able to stop, particularly in capital incentive projects. Simultaneously, essential amenities are to be provided to all the citizens before 2047 for achieving the status of "Viksit Bharat".

INTRODUCTION

The Prime Minister, Shri Narendra Modi launched 'Viksit Bharat @2047: Voice of Youth' on 11th December 20231. The Government of India set the primary goals of Viksit Bharat @ 2047 as economic growth, technological advancement, infrastructure development, social development, environmental sustainability and good governance. The primary goals of "Viksit Bharat@ 2047" cannot be achieved without availability of adequate world class physical infrastructure which require large financial and skilled human resources with dedication and commitment from all the stakeholders. To achieve these goals by 2047, all the stakeholders have to critically start planning, implementation and reviewing them in a time bound manner as infrastructure projects require long period in their planning and implementation.

Since development of infrastructure require land acquisition, financial resources and close coordination by both central government and concerned state governments, central government and all state governments have to start working in tandem to achieve the goals of "Viksit Bharat @2047. For the transparency and to develop quality infrastructure in the country, active participation of its citizens in its development process is also required.

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VISION OF "VIKSIT BHARAT @2047"

The vision of "Viksit Bharat @2047" is to transform India into a developed nation by the year 2047. Viksit Bharat @2047 is the government's vision to transform the country into a self-reliant and prosperous economy by the year 2047, the centenary year of its independence. It includes programmes in the field of economic growth, infrastructure development, technological upgradation, social empowerment, and sustainability.

ECONOMIC GROWTH AND ECONOMIC DEVELOPMENT

Economic growth is related to increase in national income and per-capita income, a measure of economic growth and is measured by Gross Domestic Product (GDP) over a long period. While economic development refers to a sustained improvement in material well-being of the citizens including social upliftment, infrastructure development is closely related to both economic growth and economic development.

Economic growth and economic development depend upon the population of a country. Economic

growth, directly influences economic growth as it is measured through per capita income. India being the most populous country in the world, has to manage its human resource for economic growth and economic development which is going to be most difficult task as youth requires employment and old citizens require government support. Therefore, India has to prepare its HR policy by which the majority of its people get employment. A developed country cannot sustain on subsidies and freebies hence India's HR management policy is important for the "Viksit Bharat".

Economic development is feasible through higher productivity, proper use of the resources and minimization of wastage and losses.

INFRASTRUCTURE DEVELOPMENT

A country can become a developed nation only with adequate, efficient, and durable infrastructure, thereafter with proper maintenance being taken up so that the citizens do not feel inconveniences. Present day infrastructure has to be smart, IT enabled and citizen friendly for the efficiency and transparency during construction, maintenance, and operation. Hence "Viksit Bharat" will require smart cities, smart energy, smart governance, smart utility services, and smart transport, based on IOT, IT and AI, making uses of robotics, quantum computing, real time observations, monitoring and communication. Since infrastructure requires land, land required for the infrastructure development will be crucial in future.

By 2047, India's population is likely to touch the figure of 164 crores, hence additional land be required for their habitats in addition to additional land required for agriculture and forest for food and environment sustainability. Since land is limited, it will become a scarce commodity and multi-storeyed buildings will be common even in small towns, while cities will have more and more skyscrapers and multi-tier roads and bridges, posing challenges during construction and maintenance. Since, cities will not be able to sustain high influx of the population, new satellite towns and cities will have to be developed and more and more facilities of cities will have to be taken to rural areas, particularly within 100 to 200 kms of the cities with the connectivity of high-speed public transport such as metro rails, trains and buses.

For sustainable infrastructure development, challenges are water stagnation and poor drainage in cities and towns during rains, construction of safe structures in flood prone areas, construction of earthquake resistant structures in earthquake prone areas, construction of dykes in coastal areas to prevent submergence, effective ban on plastic waste, solid waste management, prevention of deforestation and creation of afforestation, green energy generation, providing safe water and sewerage system, pollution control, environmental sustainability, and availability of quality materials required for the infrastructure development.

CHALLENGES AND ROADMAP FOR INFRASTRUCTURE DEVELOPMENT

India has taken up large infrastructure projects but the losses due to poor drainage, natural and man-made disasters, sub-standard construction, lack of transparency and integrity, and non-availability of required expertise and skilled workforce are posing great challenges to achieve the desired results. On the other hand, the country is still not able to provide basic amenities to the citizens. Financial resources are limited and the governments are adopting measures such as "direct benefit" to the citizens in the form of subsidy or freebies as such providing financial resources for the expensive infrastructure projects is going to be a major challenge. Another challenge is migration from rural areas to cities, resulting into encroachments, slums and unauthorized construction in the cities. Unauthorised unsafe structures and poorly planned infrastructure fail during disasters resulting into heavy losses to the nation.

LOSSES DUE TO DISASTERS

A disaster causes tremendous loss of lives, property, economy, environment and nation's resources. India is a country in which disasters like earthquakes, floods, avalanches, landslides, cyclones and Tsunamis occur however man-made disasters are also very common leading to heavy loss which put the economy to back gear. Poor planning and implementation of the drainage system and non-availability of basic amenities such as sewerage system resulting into mixing of sewage with domestic water supply leading to diseases are also creating disaster like situation during rains. For "Viksit Bharat", such losses have to be minimised. Therefore, the country has to plan and develop qualitative, and durable safe infrastructure.

CONSTRUCTION OF SAFE STRUCTURES IN FLOOD PRONE AREAS

Floods damage infrastructure such as houses, roads,

highways, railway lines, human lives, livestock, and crops leading to heavy direct losses, simultaneously stalling the routine activities thus loss of man hours of the productivity. The climate change is also resulting into floods in the areas where past data do not substantiate such floods. Therefore, a policy has to be brought out to consider High Flood Level (HFL) based on future prediction, rather than past data as climate change is likely to alter the rain pattern. Sine the country is still not planning the infrastructure based on changed scenario, loss due to floods is likely to be even more than the loss due to earthquakes as more and more earthquake resistant construction is being taken up but no proper policy is available for development and protection of safe infrastructure due to floods. To account for the present design requirements, construction of additional drainage structures and retrofitting of the existing structures may be required. A policy is required to be framed and work needs to be taken on mission mode for "Viksit Bharat".

Poor drainage has become a major issue in the entire urban areas of the country. Use of sub-standard materials, inadequate drainage system, encroachment, poor maintenance, poor municipal solid waste and C&D waste management, encroachment on lakes, ponds and open wells, and non-application of engineering in developing drainage infrastructure, all are resulting into water stagnation in the urban areas and heavy direct and indirect losses. Flash foods are also resulting due to climate change and deforestation.

Government already has a strict policy of deforestation and implemented it firmly however this policy has to be reviewed for creating sustainable infrastructure simultaneously taking up reasonable afforestation and construction of new water retaining structures to avoid flooding. Creation of man-made lakes, ponds, baolies, wells and tanks are also required to be developed in the towns and cities to meet the growing demand of water due to population increase and avoidance of wastage of rain water. The catchment areas of the rivers, streams and nallahs have to be protected and afforestation carried out to retain the rain water.

Water is going to be a scarce commodity in future as it is required for drinking, household requirements, industries and irrigation. Even though, the governments are trying to recycle and reuse of water in buildings, the major thrust is required to be accorded to saving of water in irrigation as 70-80% water is used in it and farmers still prefer to flood irrigation. Saving of even 10-15% in irrigation is likely to result of saving equal to the water required for drinking. The flood water has to be protected, stored and treated for daily use and cannot be wasted for achieving the goals of "Viksit Bharat".

MANDATORY CONSTRUCTION OF EARTHQUAKE RESISTANT STRUCTURES IN EARTHQUAKE PRONE AREAS

Large unsafe construction has been carried out in many parts of the country including in earthquake prone areas. For "Viksit Bharat", the practice of constructing houses without structural design is to be stopped. This would require a policy change at the national level and capacity building of the masons, contractors, architects, engineers and structural designers engaged in the construction. All the structures have to be structurally safe and practice of constructing non-engineered unsafe structures is to be stopped. The Government has already taken up the scheme "Housing for All" as such these structures are safe and will eradicate slums in the country. However, there are still large number of non-engineered structures in the country, whose owners may or may not be capable of bearing extra expenditure of retrofitting. In many cases, even government buildings are not constructed as per latest codes as such they also require seismic retrofitting. For "Viksit Bharat", a policy has to be framed so that the all the structures are safe during earthquakes as 2047 is not very far from the consideration of the life of a building structure. The challenge of stopping unauthorised non-engineered unsafe structures may be gauged by the fact that Delhi itself has 1642 such colonies[2].

MANDATORY CONSTRUCTION OF CYCLONE PRONE AREAS IN CYCLONE PRONE AREAS

India also has a long coastline as such most of the coastal cities are prone to cyclones. In past few years, India has taken up mitigation measures for preventing loss of lives by early warning system and peoples' evacuation. However, all the structures have not been found safe during the cyclones (Figure 1). Therefore, new construction has necessarily to be safe from the cyclones and existing structures have to be retrofitted for qualifying as cyclone prone structures in such areas. Further, a policy has to be framed for the consultants who are experienced in designing cyclone prone structures. There is a need to enhance the capacity building of designing and constructing cyclone resistant structures in coastal areas.

Fig. 1: Cyclone blew roof of Vizag Airport

Fig. 2: Mumbai Railway lines Submerged

Some coastal cities may experience submergence in coming future, at least the low-lying areas of coastal cities like of Mumbai (Figure 2). For "Viksit Bharat", such situation must not arise hence planning has to be started immediately in such cities by reclamation of land for construction of dykes or bunds, and even special structures like raised canals/lakes where this water can be stored or taken to the desired areas or create infrastructure to pump out water to avoid submergence of the cities. Planning has to be started immediately as these structures may require huge sum of money, and time for execution. Laws and guidelines have to be made flexible to acquire the land in coastal areas for infrastructure development.

PREVENTION OF MAN-MADE DISASTERS

In the country, large number of man-made disasters occur due to poor design, poor quality of construction and poor maintenance. Such disasters lead to accidents at the work sites and sometimes collapse of buildings, bridges and other structures (Figure 3 and 4). Fire is another man – made disasters leading to loss of lives and property. For "Viksit Bharat" such disasters have to be controlled by adopting quality as a basic tool during design, construction and maintenance. A strict quality policy has to be followed with complete transparency, and corruption free environment. Stern action needs to be taken against defaulters including the contractors within a pre-determined time frame. Even the data of road accidents indicate of its being a disaster as the report of "The Times of India" dated 12 November 2024 indicates that 15 lakhs people died in road accidents in Indian roads in India in ten years[3].

Fig. 3: Collapse of unauthorized Building

Fig. 4: Collapse of Bridge

PROVIDING BASIC AMENITIES

Basic amenities include shelter, water supply, sewerage system, energy, education, health and transport infrastructure. At present, these services are still lacking or require improve mention a large scale in the country to qualify for being a developed nation. Providing water and sewerage system is extremely essential as it is also related to hygiene and health. The government has already started "Jal Jeevan Mission" and thus everyone is likely to get potable water by 2047 but sewerage system is not available in many cities, towns and rural areas. In many places, ground water is extracted from

the nearby areas where septic tanks and soak pits are constructed contaminating ground water, an unhygienic state leading to water borne and other diseases. In some places, even septic tanks and soak pits may not be available. As per the article published in Stanford Social Innovation Review, 93 percent of sewage finds its way to ponds, lakes, and rivers without treatment4. Even though the data may be ten years old but there may not be complete change on the ground from the report. Hence providing sewerage system has to be taken up on mission mode in the entire country. For a developed nation, availability of sewerage system and treatment of sewage is a must.

Infrastructure of poor drainage is taking serious turn in the country as during rainy season many towns and cities are getting submerged resulting into heavy direct and indirect loss. Such situation is not entirely due to floods as the data indicates less rainfall than earlier years for Delhi (Figure 5) but development of infrastructure without drainage system or with improper drainage (Figure 6). "Viksit Bharat", neither can sustain losses due to such state of affairs nor truly called as "Viksit".

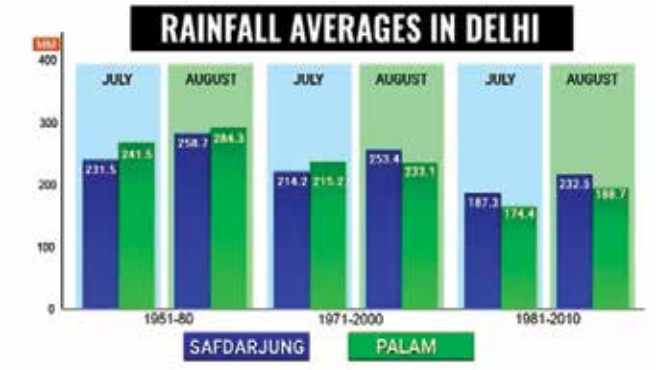

Fig. 5: Rainfall data

Fig. 6: Delhi poor Drainage

Another area where immediate attention is required is control of stray animals in the country which include dogs, cats, cows, monkeys etc. Such animals can be seen in cities, towns, streets, parks, roads, highways, railway tracks, and other places. For "Viksit Bharat", country needs a policy of controlling such stray animals without affecting the routine life of the citizens. The problem of stray animals can be understood by the population of stray dogs and stray cattle being 203.31 lakhs as per 2019 census5.

USA consumes 277 GJ/capita/year, South Korea 240 GJ/c/year, France 134 GJ/c/year, Japan 141 GJ/c/year while India 27.3 GJ/c/year as per the data of 20236. As a country moves towards a developed nation, energy consumption increases hence "Viksit Bharat" during 2027 will require more than five times energy even to reach at the level of Japan of 2023. For industrialization, the demand will further go up hence energy sector will require massive energy generation for "Viksit Bharat @ 2047".

A developed nation has quality infrastructure and quality education and health so "Viksit Bharat" will also need it. The government has already adopted privatization in education but the quality of education is not upto the mark which can be equated to a developed nation. Hence, policy has to be reviewed, modified and regulatory infrastructure strengthened for quality education and strict implementation for developing India into "Viksit Bharat". The situation can be realized from the news like "Over 550 engineering colleges and institutions affiliated with AICTE have shut shop in the last six years7", AICTE to shut down 800 engineering colleges across India8, Anna University to shut 12 colleges with less than five per cent enrolment; students to be shifted9".

SUSTAINABILITY OF INFRASTRUCTURE DEVELOPMENT

Sustainability of the infrastructure includes environmental sustainability, sustainable energy, use of quality materials, quality construction and maintenance, prevention of wastage, R&D, and capacity building in quality infrastructure.

ENVIRONMENTAL SUSTAINABILITY

Environmental sustainability encompasses afforestation, water sustainability, energy sustainability and net zero carbon emissions. Prime Minister Narendra Modi has announced a net zero target by 2070 at COP26 in 202110. The government has already adopted the principle of net-zero carbon emissions hence adoption of green

infrastructure will have to be planned and executed as a routine measure by every engineer, policy maker and industrial entrepreneur. Since, energy requirement for "Viksit Bharat" will be multi-fold, energy generation and energy security are going to be a challenge for the engineers.

ADOPTION OF QUALITY AS A BASIC TOOL

Government of India has implemented "Make in India" policy and industrialization is being promoted in the country. This has to be continued and taken up on large scale with quality products. Quality has to be inculcated in the minds of the individuals of the entire country. Robotics and computerization have to be included in the manufacturing process to assure the quality including manufacturing of industrial quality products required for the infrastructure development. India has large human resource which has to be trained and utilized in the upcoming sectors based on resource availability in the country and demand of the domestic and global market.

A developed nation adopts quality without which it cannot be termed as a developed nation. For "Viksit Bharat", quality concept has to be inculcated in the mind of every engineer right from the engineering college. Stern action has to be taken in case the "quality" is compromised against those engineers and the contractors by enacting necessary laws for penalising them for sub-standard work and even those manufacturing and supplying sub-standard materials. Further, standardisation of categorising quality materials is required so that a common user can identify it easily. For example, tiles manufactured by different companies may categorise their best quality material in a standard way only. No material should be allowed to be manufactured without conforming to the prescribed standards and without certification. The standards should also be revised for upgrading standards for achieving better quality.

Engineering has to be included in maintenance as poor maintenance leads to higher wastage, frequent replacement of the infrastructure leading to wastage of resources, pollution, large inconvenience to the users, and corruption. "Viksit Bharat" should spend little on the maintenance by adopting quality construction simultaneously implementing quality maintenance. The concept of life of original construction, and of renovation and maintenance has to be implemented and in case of failure, responsibility is to be fixed on the engineers and contractors. Till responsibility and accountability is not fixed, fear factor among those defaulters will go on missing leading to corruption and poor quality. "Viksit Bharat" will only be possible if the country is able to eradicate corruption to a great extent from the society.

PREVENTION OF WASTAGE

A developed nation has to avoid, and minimize the wastage and then reuse and recycle the wastage. Therefore, Viksit Bharat will have to avoid and minimize the wastage by planning and construction of quality infrastructure and thereafter recycle and reuse waste like waste water, and construction & demolition waste regularly.

INVESTMENT IN R&D AND CAPACITY BUILDING

Unfortunately, Research and Development (R&D) in the civil engineering construction is not related to construction industry requirements. Therefore, theoretical research is carried out in the institutes and universities. There is a need of construction industry-oriented research, particularly for major infrastructure projects. Organizations should fund research projects at the time of preparation of feasibility study or DPR of such projects so that appropriate materials and techniques are recommended for the projects' execution.

"Viksit Bharat" will require top quality engineers in all the fields as they are to work in the country and prove themselves hence capacity building of the engineers is to be continual. The engineers should be able to work in the field with short term orientation training. At present, there is a wide gap between field working and class room education. May be core engineering has to be split into specialised fields like civil engineering into building construction, highway engineering, water resource engineering, railway engineering etc. to include industry-oriented training and/or the government has to make mandatory paid internship of at least one year with the industry like doctors to have industrial training.

For carrying out infrastructure development, there is no system of making contractors and construction companies accountable for sub-standard work except blacklisting them who more often get registered with other name. Strict laws need to be enacted against poor quality construction companies and life cycle concept to be included in the contracts. Also, strict action against those carrying out unauthorised unsafe construction and those constructing slums is required without any political protection to them.

GOOD GOVERNANCE AND RESOURCES

Good and corruption free governance is the key of success to "Viksit Bharat @ 2047". Good governance has to be attained through transparency, digitalization, and citizen centric governance in which citizens and national interest are given preference over self-benefit and self-achievements. This will result into saving of availability of financial and other resources which can be utilized for the infrastructure development.

For taking up infrastructure development required for "Viksit Bharat", considerable financial resources are required at central and state government levels. Most of the State governments are not having adequate financial resources as they are incurring high expenditure on freebies or subsidies promised to the public. In such cases, the "Viksit Bharat @2047" will remain a dream if financial resources cannot be arranged. Further, it will require alternate innovative technologies in place of traditional construction techniques taking considerable time for execution, and alternate materials for sand, aggregates, and stones. The hurdles in getting approvals of the plans, drawings, project commencement, tree cutting, etc from various local bodies and government's clearance are to be removed as they take considerable time as taking approvals itself is a great challenge.

CONCLUSION

Viksit Bharat @ 2047 has to be a strategic national mission to make India a developed nation. The country has to focus on economic development which is feasible through higher productivity, proper use of the resources and minimization of wastage and losses.

The challenges of "Viksit Bharat @ 2047" include providing basic amenities, constructing quality infrastructure safe from the natural and man-made disasters, and creating corruption free good governance around the country.

Roadmap of "Viksit Bharat @ 2047" will focus on economic growth of the country, economic development of the citizens, quality infrastructure, IT and AI based digital transformation, quality education, and environmental sustainability.

The country will require strong policy implementation, public-private partnerships, active citizen participation, good governance, industry-oriented R&D, and coordinated planning and implementation by the central and state governments to arrange the financial resources, and removal of hurdles of encroachment and approvals.

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A NEED FOR TECHNOLOGY AND INNOVATION EXCELLENCE WITH REFERENCE TO NATIONAL WATER SUPPLY MANAGEMENT AND VIKSIT BHARAT 2047 AND INFRASTRUCTURE DEVELOPMENT

Dr. Prakash R. Mutyala*

Abstract

The year 2047 is supposed to be a land mark in Indian history, as the Nation attains the 100th year of Independent and Sovereign country. The present paper aims to analyse, evaluate and propose the need for an appropriate Technology and Innovative Models of Excellence in improvising the Water Supply to living objects includes human, plants, and animals in India.

India has largest sources of water in the World. However, optimization in terms of appropriate utilization is lacking and this short coming calls for the Technology and Innovation Excellence to focus on attaining equilibrium condition of the demand and supply of water resources and consumption. The author brings out the innovative concepts in the ambit of regional planning, construction management, and economic equilibrium considering the basic needs of human and living objects.

The paper supports the Private Sector participation in undertaking the National Water Supply Management, after realising the potential of the Private Sector management in India, and in supporting critical needs of Indian Population. The Governments at State and Central might support the private sector investment in the water supply management which until now is dismal. The participation of private sector shall bring out the latest technology and innovative capacities and practices to meet with the basic needs of Indian population.

INTRODUCTION

According to Hindu mythology, King Bhagiratha did not construct a dam in the Himalayas. The Hindu mythology scripted that he brought River Ganga from heaven. The River Ganga believed to be very powerful and devastating in touching the Earth. Lord Shiva was invoked for the solution. Lord Shiva allowed River Ganga to flow through his hair (Rishi Kesh) and reduced the flowing speed of River Ganges. The Hindu Mythology portrayed this as an act God but not called it as dam. In Engineering domain one can portray this as dam constructed meticulously by humans and allowed to flow in to Indian territory. Our ancestors believed that it is Bhagirath Prayatna a term used by generations of Indians as a praise for a impossible tasks in day to day life. The author being inspired by the above legend which has been motivated to undertake a self financed project on National Water Supply Management aligning to the goals and objectives of Viksit Bharat 2047 and Infrastructure Development.

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We are very well award that, the water resources all over the World is depleting fast and continues to be further deteriorate in years to come. India is no exception. In addition, the Indian population kept on increasing since last few decades thanks to the efficient Health Care system in India and highest immunity levels. The water is a major component in food and nutrition for all the Indians. Indians consume more quantity of water as compared to the other nations. Though India has largest resources of water, however a major part of it is being wasted or drained to in to the sea. An efficient water conservation and usage of water supply at National Level is unexplored.

On cursory survey of literature on water supply management in India highlights lacking both at literature and modelling. A scanty published works are available however an efficient blue print of the Total Water Supply Management is missing. Combined with the technology of Remote Sensing tools, AI tools and Technical Manpower, the country could easily prepare A National Blue Print for the Water Supply Management in India. Let us examine what the past Prime Ministers of India commented on Water Supply Management in general and particularly of its perspective plans in the following pages.

Atal Bihari Vajpayee, past Prime Minister of India, laid significant emphasis on water conservation and management, recognizing the growing water crisis in the country.

Here are some key aspects of Vajpayee's focus on water supply and elaborated in appropriate wordings by the author.

- **National River Linking Project (NRLP)**

India has several perennial rivers and equally so most of its water either drain off or let off in to oceans. One is well aware that it is Bhagirath's Prayatna to link Indian rivers due to the fact that the geography of the nation is uneven and undulating from Kashmir to Kanyakumari, and Gujarat to Agartala. Besides undulation there a peaks and mountains which might obstruct the linking of water from rivers and their free flow due to gravity. It is essential some sort of pressure creation is essential to enable water flow. This project might be the most crucial for India in terms of security of the country, economic "Big Push" and centuries long benefits. Nothing is impossible to Indian enterprise to bringing the River Linkage Project to reality as the country has technological competence , skilled manpower, economic strength. However political will and dedicated channelising of funds from central budget is essential. India got its freedom from food supplies, followed by shelter and clothing to a large extent compared to the pre-independence era. Some more sacrifices are required to bring this dream project to reality. One would appreciate that India has better linkages of road and rail transport as compared to many nations in the World. The Rivel Linkage task would go as legendry of the present living population's sacrifice in the annals of history of India.

- **Water Conservation and Judicious Use**

Water has become precious commodity due to its non availability to several rural and remote areas of India. Even Urban areas are strained due to non availability of required quantity of water per person and required quality standard of water. This calls for the conservation and judicious use of the water by every one no matter where he lives.

- **Addressing Groundwater Depletion**

The ground water depletion phenomenon is attributed to the natural absorption of water in to the earth's surface due to afforestation. One another reason is attributed to the excessive mining activity includes, mineral and metal exploration, crude oil extraction, and massive construction activity. This problem could be resolved once the River Linkage Project is brought in to the existence instead of restricting cultivation and construction activities.

FOCUS ON BASIC NEEDS

Several rural regions in India have inadequate drinking water supply. Several rural habitants have to fetch water by walking several kilometres distance . The quality of such water found to be a great health hazard. This aspect needs National Focus on this serious basic needs and it is time to free the nation from this catastrophe. This issue can be addressed as the major focus in undertaking the National River Linkage mission.

- **Improving Sewerage Systems**

The water contamination occurs frequently due to the inadequate water supply and stagnation of drainage water. Most of our towns are yet to have the underground , free flow drainage network. The stagnated water is responsible in spreading diseases and breading mosquitoes .Indian toilets do not have adequate water storage system there fore such toilets are not being used by the people even though they were constructed by local bodies. A good inflow and out flow of water might remedy this situation.

- **Community Involvement and Policy**

Linkage of Rivers is a National Mission as the project is equated with Bhagirath Prayatna. The mission require political strong will, entire nation's support, technical and administrative will by experts and least but not least the heavy flow of National Domestic Product. We have to 'Bite the Bullet' as this project will pave the way for absolute strong nation in the World. After food supplies water will play major diplomacy in brining the other countries to the good will of India. It might take several years to accomplish the project and it will ensure the realistic patriotism of every Indian as the fruits of the project is national pride and necessity. It is every Indian dream when all our Rivers of India flow crisscross to each other with a mighty engineering marvel of the Era where India gets freedom from the drinking water menace. As supplementary our crop production will be able to feed the entire World as arable lands would tremendously increased.

INNOVATIVE IDEAS IN IDENTIFICATION OF WATER SUPPLY UNITS

India has weak statistical estimates of comprehensive water supply resources in terms of quantifiable units.

These resources include wells, rivers, ponds and man made water storages. It is proposed to compile the statistical data by using remote sensing technology. A statistical methodology/model is required to bebrought in for quantifying the quantum of water resources in the country. A good data base is a back bone to undertake the national projects like Linkage of rivers.

CONCEPT OF REGIONAL WATER SUPPLY ENDOWMENT (RWSE)

The concept of RWSE refers to the total water resources available in a given region, country, or spatial unit. It involves taking a holistic view of the water supply and measuring it against current and projected water demand. It is an easier way to number the Regional Endowment Units in country. It serves the purpose of interlink of given Regional Water Endowment units. While one is contemplating to bring out the linkage of Rivers, it may be clarified that , linkage of Rivers mean linkage of all the water resources in to single pocket called Water Endowment Unit.

Following are the major components of Regional Water Endowment.

A typical Water Supply Endowment Consists of Following

- Surface water: Rivers, lakes, and wetlands.
- Groundwater: Water found beneath the Earth's surface in aquifers.
- Other forms of water: This can include solid forms like glaciers and snowpack, which contribute to water supply upon melting.
- External water sources: Water flowing in from trans boundary rivers or imported virtual water (water embedded in traded goods and services).

- **Water Demand Estimates/Parameters**
  - Amount of water used:
  - Variation in use:
  - Sectors of use:
  - Purpose of use:
  - Water recycling/feedback:
  - Time scales:

- **Data and Analysis**

  To understand water endowments effectively, good climatological, physical, and socio-economic data are crucial.

  - Assessment of demand and supply:
  - Evaluation of development alternatives:
  - Policy performance assessment:

In essence, water endowment is about understanding a region's natural water capital and how it can meet its various water needs, considering both present and future scenarios. It's a critical concept for achieving water security and sustainable water management.

Water Storage Construction Technology

Types of Water Storage Structures

- Overhead Tanks:
- Tanks
- Underground Tanks:
- Modular Tanks:
- Pillow Tanks/Flexible Tanks:
- Slimline Tanks:

- Reservoirs:
- Dams:
- Cisterns:
- Stepwells:

Construction Materials

- Plastic (Polyethylene/HDPE):
- Concrete:
- Steel
- Fiberglass

Innovative Technologies and Trends

- Smart Monitoring & IoT Integration/AI Tools
- Modular Design:
- Eco-Friendly and Sustainable Materials:
- Advanced Filtration and Purification:

- Rainwater Harvesting Systems:
- Underground Storage Systems:
- Decentralized Water Systems:
- Self-Cleaning Tanks:
- Integrated Pump Systems:
- Elevated Tanks with Improved Structural Design:

Cost-Effectiveness and Sustainability

- Material Selection:
- Rainwater Harvesting:
- Energy-Efficient Technology:
- Preventing Water Loss:
- The future of water storage technology is moving towards smarter, more sustainable, and adaptable solutions that can address global water challenges efficiently.

Concept of Water Grid

A water grid is essentially a sophisticated network designed to manage and distribute water resources efficiently. Think of it like a power grid, but for water. It connects various water sources, treatment facilities, and consumers through a system of pipelines, pumps, and control centers.

Water Grids Working System:

Traditional water distribution systems often rely on a centralized source and a branching network. Water grids, especially "smart" water grids, employ a more interconnected, "gridiron" or "loop" pattern. This means water can flow through multiple pathways, offering greater flexibility and resilience.

Key components and how they work:

- Pipelines:
- Nodes and Junctions:
- Pump Stations:
- Storage Tanks:
- Sensors and IoT Devices:
- Data Analytics and AI/ML Algorithms:
- Smart Meters:
- Control Centers:

Benefits of Water Grids:

- Minimization of Redundancy and Reliability:
- Uniform Pressure Distribution:
- Reduced Water Loss:
- Improved Water Quality:
- Increased Operational Efficiency and Cost Savings:
- Enhanced Customer Service and Engagement:
- Scalability:
- Resilience to Climate Variability:

Challenges of Water Grids

- High Initial Costs:
- Data Management and Integration:
- Aging Infrastructure:
- Water Leakage:
- Inefficient Water Management Practices:
- Policy and Regulatory Frameworks:
- Cyber security Risks:
- Public Acceptance and Fair Pricing:

EXAMPLES OF SUCCESSFUL WATER GRIDS

- South East Queensland (SEQ) Water Grid, Australia: This is a notable example of an intelligent embedded system with duplex pipelines for two-way water movement, treatment facilities, hydropower, pumping stations, and diverse water sources, including recycling.
- Many cities and utilities worldwide are implementing Smart Water Grid technologies, leveraging IoT sensors, AI, and data analytics to optimize their water distribution systems and improve efficiency.
- In essence, water grids represent a crucial step towards more resilient, efficient, and sustainable water management, particularly in the face of increasing global water scarcity and climate change. The shift towards "smart" water grids, leveraging advanced technologies, is key to addressing future water challenges.

- The water grid concept might be well suited to Urban Areas such as Mumbai, Delhi, Kolkatta, Chennai and Bengaluru where the processing cost due to Water Grid shall match the life styles of these metropolitan cities.

EQUILIBRIUM COST BASED ON WATER SUPPLY AND DEMAND

Water demand is estimated to be higher keeping in view the increase in population, brining more cultivable lands for cropping and various other uses. It is appropriate to calculate cost based pricing of water rather than demand and supply determined prices (equilibrium pricing).In the long run the entire cost of laying pipes, pumping water and cost of power to pump will gradually tend towards affordable cost to the nation. Example can be seen in case of Indian Railways, National High Ways and Indian postal system.

A HYPOTHETICAL AND CONCEPTUAL MODEL FOR NATIONAL WATER SUPPLY SYSTEM BASED ON WATER ENDOWMENT CONCEPT

In the previous sections of the present paper, two important systems such as Endowment and Grid systems are being identified towards National Water Supply by pooling the different water resources locally and river water connecting major rivers in India. While the Grid System is highly sophisticated, and needs high technology through AI tools, the alternative system , being Water Endowment System is simpler and affordable to Indian conditions. The Table 1 brings out the difference between the Water Grid System and Water Endowment System towards linking of rivers and pooling the local water resources.

Table 1: Comparison of Water Grid and Water Endowment System in Linking Rivers and Other Natural Water Resources

Parameter	Grid Water System	Endowment Water System
Technology	Require AI tools	Simpler tools
Storage	• Over head tanks • Modular Tanks • Flexible Tanks • Slimline Tanks	• Reservoirs • Dams • Cisterns • Stepwells
Construction Material	• Plastic • Concrete • Steel • Fibre glass • Ferrocement	• Open tank • Concrete • Steel • Clustered Tanks
Cost Variables	• Pipes • Mesh and Concrete • Filtration • Under ground storage • Self cleaning • Integrated Pump systems • Elevated Tanks • Electricity	• RCC pipes • Integrated Pumping systems • Gravity Flow • Clean Energy from Hydrogen, Solar, Wind , Thermal, Tidal • Fencing of Storage area

METHODOLOGY

Based on real life situation of India, the Water Endowment System is more suited in connecting various water resources, where Rivers are considered to be prime movers, potential resource, and reliable source. Following are the step wise methodology conceived by the author in integrating River Waters along with other perennial water resources with an objective to provide "Water to All" .

- Survey and list the rivers and their locations
- Measure the length of Rivers and their routes
- Along with River Routes, record the topography of lands either side of river.
- Identify the Towns and Cities aligning the Rivers on either side along with quantum of lands available for construction of Endowment Units.
- Identify the water storage in the forms of , tanks, ponds, and their connecting water streams and water falls.
- Using some geometrical, heuristic method identify the locations for Water Endowment Units in the country. It could be Eij (i= 1,2,3,...n and j=1,2,3,...n). Where E is Endowment Unit in the country, 'i' represent the inflow of water and 'j" is the out flow of water to other Endowment Units in the country.
- Install Electrolyzers to produce required quantity of Hydrogen at each of the Endowment Units. Further the Electrolyzers be connected to the Electricity Generator to produce electricity to the Pumping Station located near by Endowment Units. The residual of Oxygen produced may be transported to Health Centres around the Endowment Units. Since Electrolyzers input is water and the Electrolyzers gets the power from the mechanism of cascading of power there is no power shortage conceived. The non conventional energy if identified near by places at Endowment Units, the same could be supplementary inputs of energy and can be an input to the Electrolizers.
- Connect the Endowment Unit in the country using cobweb network of pipes as well as Rivers for feeding the Endowment Units (Eij) with water and as well distributing water as input to the other Endowment Units.

GOVERNMENT AND PRIVATE PARTNERSHIP

The National Water Supply Mission is national project. The participation of privates sector is highly essential. The participation of private sector shall bring out the latest technology and innovative capacities and practices to meet with the basic needs of Indian population.

CONCLUSION

As mentioned in the beginning of this paper , to is highly complex and tardy project to implement. If one desires to achieve the significant objective Viksit Bharat 2047 and Infrastructure Development, it is essential to make up strong will to bring water to door step of everyone, the life line of many Indians who were deprived of the clean drinking water.

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INNOVATIVE FACADE MATERIALS: REDEFINING THERMAL COMFORT IN RESIDENTIAL BUILDINGS

Aditya Sanyal* And Dr. Nirmita Mehrotra**

Abstract

The facade of a residential building is pivotal for achieving thermal comfort and energy efficiency. Traditional construction methods often lead to high energy consumption due to poor thermal performance, necessitating innovative solutions. This article explores cutting-edge facade materials and technologies that passively regulate indoor temperatures, significantly enhancing comfort and sustainability in residential buildings. We delve into the application of Phase Change Materials (PCMs), which store and release latent heat to stabilize indoor temperatures, drastically reducing heating and cooling loads. Aerogels, known for their superior insulating properties even at minimal thickness, are examined for their ability to minimize heat transfer. The article also discusses dynamic and smart facades, including electrochromic glass and responsive shading systems, which adapt to changing environmental conditions for optimal day lighting and solar control. Furthermore, the integration of bio-based materials like hempcrete and the benefits of green facades are highlighted for their natural insulation and cooling effects. The piece emphasizes a holistic design approach, combining these innovations with optimized glazing and effective shading strategies to create energy-efficient, comfortable, and environmentally responsible living spaces. This integration of advanced materials and intelligent design is crucial for meeting future energy demands and improving occupant well-being

INTRODUCTION

In the evolving landscape of sustainable architecture, building envelopes—particularly facades—play a pivotal role in regulating indoor environments and enhancing occupant comfort. Traditionally perceived as mere protective layers, facades have now emerged as dynamic, multifunctional components capable of responding to environmental stimuli, optimizing energy use, and significantly improving thermal performance. As climate change intensifies and energy efficiency becomes a global priority, the need for innovative facade materials in residential construction has never been more critical.

Thermal comfort, defined as the condition of mind that expresses satisfaction with the thermal environment, is deeply influenced by a building's facade system. In residential buildings, where occupants spend prolonged periods indoors, maintaining stable and comfortable indoor temperatures throughout the day and across seasons is essential for health, productivity, and overall well-being. Conventional materials such as brick, concrete, and glass often fall short in meeting the evolving thermal demands of buildings, particularly in regions with extreme or fluctuating climates.

Recent advancements in material science have led to the development of cutting-edge facade technologies, including phase change materials (PCMs), bio-based composites, aerogels, smart glazing, and double-skin facades. These materials are engineered to not only provide structural integrity and aesthetic value but also actively contribute to thermal regulation by managing solar heat gain, insulation, ventilation, and radiant heat exchange. For instance, bio-based PCMs incorporated into wall assemblies can absorb excess heat during peak hours and release it during cooler periods, thereby flattening indoor temperature swings and reducing reliance on mechanical heating and cooling systems.

Moreover, adaptive and responsive facade systems align with the principles of passive design by integrating naturally available resources—such as sunlight, wind, and ambient air—to maintain thermal equilibrium. These technologies, when thoughtfully applied, can dramatically reduce the operational energy consumption of residential buildings, contributing to both climate mitigation and energy resilience goals.

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This chapter explores the transformative potential of innovative facade materials in redefining thermal comfort within residential architecture. It examines their material characteristics, performance behavior across climates, integration strategies, and real-world applications. By bridging the gap between scientific innovation and architectural design, the study highlights how next-generation facades can support sustainable, energy-efficient, and thermally comfortable living environments.

NECESSITY OF INNOVATIVE FACADE SYSTEM

Rapid urbanization, climate change, and rising energy costs are compelling architects and engineers to re-conceptualize the residential building facade as an active, multifunctional system rather than a static barrier. Advances in material science—ranging from bio-based phase change materials (PCMs) and aerogels to electrochromic glazing, vacuum insulation panels (VIPs), and biomimetic surfaces—are enabling facades that sense, store, modulate, and even generate energy while enhancing indoor environmental quality. This paper synthesizes the state of the art in innovative facade materials with a focus on their capacity to improve thermal comfort in residential buildings, outlines a simulation-based methodology for performance assessment across climates, and discusses integration barriers, life-cycle implications, and pathways for large-scale adoption. Results from the reviewed literature indicate that properly selected and integrated materials can reduce heating/cooling loads by 15–40%, flatten diurnal indoor temperature swings by 2–6 °C, and improve adaptive thermal comfort compliance by up to 30% without compromising daylight or ventilation potential. The paper concludes with a research agenda emphasizing hygrothermal durability, bio-based circularity, digital twins for operation-phase optimization, and standardized comfort-centric metrics for facade evaluation.

THERMAL COMFORT AND THE ROLE OF FACADES

Thermal comfort is governed by six primary factors: air temperature, mean radiant temperature, air velocity, humidity, metabolic rate, and clothing insulation. Facades influence four of these directly (air and mean radiant temperature, air velocity via infiltration/natural ventilation potential, and humidity via hygrothermal buffering). The dynamic modulation of solar gains, conductive heat transfer, and long-wave radiation exchange is therefore central to comfort-oriented facade design.

In climates with high diurnal temperature swings or seasonal reversals (e.g., composite climates), materials that store and release heat (PCMs) or throttle solar gains (electrochromic glazing) can substantially reduce the amplitude of indoor temperature variation, thereby increasing the proportion of occupied hours within adaptive comfort bands (EN 16798-1; ASHRAE 55).

STATE OF THE ART IN INNOVATIVE FACADE MATERIALS

Phase Change Materials (PCMs)

PCMs store latent heat during phase transition, buffering indoor temperatures around their melting point. Bio-based PCMs (e.g., fatty acids, vegetable oils, and their eutectic blends) add sustainability and lower embodied carbon while offering tunable transition temperatures aligned with residential comfort bands (18–28°C). Encapsulation strategies (micro-/macro-encapsulation, shape-stabilized composites) enable integration into plasters, gypsum boards, mortars, or sandwich panels (Kuznik et al., 2011; Soares et al., 2013). Reported outcomes include peak load shaving (10–30%), delayed peak indoor temperatures (1–3 h), and improved comfort hours (10–25%) (Ascione et al., 2014; Pomianowski et al., 2013) as show in fig 1.

Key challenges: long-term phase segregation/

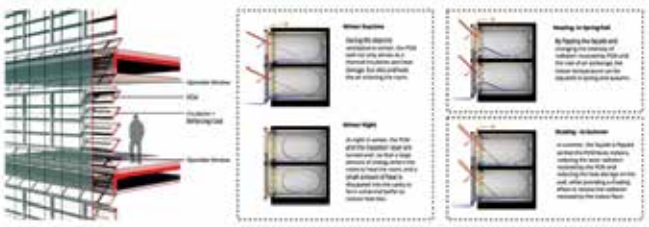

Fig. 1: Phase change material used as building facade integrated in glass operable window

leakage, cycling stability, thermal conductivity enhancement (graphite, metal foams), and recycling/end-of-life strategies for bio-based systems.

Aerogels and Nano-porous Insulations

Silica aerogels combine ultra-low thermal conductivity (~0.013–0.020 W/m•K) with high translucency, enabling slim, highly insulating facade elements and improved daylight autonomy (Baetens et al., 2011). Their use in glazing spacers, plasters, and curtain wall infills yields high R-values without excessive wall thickness. Cost and fragility

remain barriers, but recent composite aerogel blankets improve robustness and installation feasibility.

Fig. 2: Aerogels insulation board used as facade in roofing

Electrochromic and Thermochromic Glazing

Electrochromic glazing (ECG) modulates solar heat gain and visible light transmittance under a low-voltage stimulus, providing active control over indoor temperatures and glare (Granqvist, 2014).

Fig. 3: Electrochromic Glazing (ECG)

Thermochromic and phototropic films respond passively to temperature or light intensity. In residential settings, ECG can reduce cooling energy by 10–20% while improving daylight quality; however, cost, control algorithms, and integration with natural ventilation strategies require design attention.

Vacuum Insulation Panels (VIPs)

VIPs deliver R-values an order of magnitude higher than conventional insulation at thicknesses of 20–30 mm (Jelle, 2011). They are suitable for retrofits in dense urban housing where space is constrained. Thermal bridging at panel edges, risk of puncture, and performance degradation over time necessitate careful detailing and quality assurance.

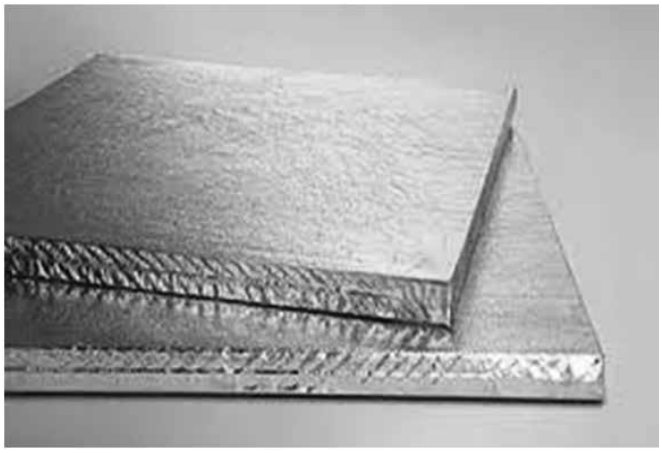

Fig. 4: Vacuum Insulation Panels (VIPs)

Dynamic/Responsive Shading Membranes

ETFE cushions, kinetic facades, and morphing biomimetic systems inspired by plant hygromorphs regulate solar gains, daylight, and ventilation pathways (Loonen et al., 2015). While more common in iconic public buildings, lighter, low-cost variants are emerging for multi-family housing.

Table 1: Summary of Innovative Facade Materials for Thermal Comfort in Residential Buildings

Sr. No.	Material Type	Key Properties	Thermal Comfort Benefit	Challenges/ Limitations	References
1	Bio-based Phase Change Materials (PCMs)	Latent heat storage, temperature regulation (18–28°C), renewable sources	Reduces indoor temperature swings (2–6°C), peak load shaving (10–30%), comfort hour gains	Phase segregation, leakage, low thermal conductivity	Kuznik et al. (2011); Soares et al. (2013)

2	Silica Aerogels	Very low thermal conductivity (~0.013 W/m•K), translucent	High insulation with reduced thickness, improved daylight use	Fragile, high cost, dusting over time	Baetens et al. (2011)
3	Electrochromic Glazing	Variable transmittance, active solar control	Dynamic shading, 10–20% cooling energy saving, improved glare control	Expensive, needs control system, risk of over-shading in winter	Granqvist (2014)
4	Vacuum Insulation Panels (VIPs)	High R-value in small thickness (~20 mm)	Space-efficient insulation, 20–50% heating energy reduction	Susceptible to puncture, edge thermal bridging	Jelle (2011)
5	Thermochromic/ Thermotropic Films	Passive change with temperature or solar radiation	Seasonal adaptation, peak solar heat gain reduction	Slow response, limited switching range	Loonen et al. (2015)
6	Dynamic Shading Membranes (ETFE, etc.)	Adjustable solar control, lightweight, often kinetic	Improved solar shading, enhanced daylight, passive ventilation coupling	High maintenance, limited durability	Loonen et al. (2015)
7	Bio-based Composites (hemp-lime, etc.)	Hygrothermal buffering, carbon-negative	Improves indoor humidity and latent cooling, reduces discomfort in humid climates	Lower insulation value, thickness required	Collet & Pretot (2014)
8	Building-Integrated Photovoltaics (BIPV)	Solar energy generation + thermal decoupling	Reduces solar gain on walls, contributes to zero-energy targets	Initial cost, design complexity	Zhou et al. (2012)

IDEAL CASE STUDY OF APPLICATION OF BIO-BASED PCM FACADE PANELS IN A RESIDENTIAL BUILDING, DELHI, INDIA

Overview

A two-story residential prototype building located in Delhi, India, was selected to evaluate the performance of bio-based PCM-integrated facade panels under composite climatic conditions. The climate in Delhi features hot summers (up to 45 °C), cold winters (down to 5 °C), and significant diurnal temperature variation, making it ideal for testing thermally responsive envelope systems.

Building Description

Total Floor Area: 210 m²

Wall Type: Double-brick cavity wall retrofitted with interior bio-PCM plasterboards (melting point: 26 °C)

Glazing: Double-glazed low-E windows (SHGC 0.32)

Ventilation: Operable windows with night flushing strategy

Cooling: Split air conditioning units (only used during peak hours for control case)

Simulation and Monitoring Setup

The study used Energy Plus 9.6 to simulate two variants:

1. Baseline Case: Conventional insulated walls (U = 0.45 W/m²•K)
2. PCM Case: Same wall with inner layer replaced by 12 mm bio-based PCM plasterboard (latent heat: 150 kJ/kg)

Data was collected from March to September, covering pre-monsoon and monsoon periods.

Results

Sr no.	Parameter	Baseline Case	PCM-Integrated Case	Improvement
1.	Average Indoor Daytime Temperature (°C)	31.2	28.5	↓ 2.7 °C
2.	Number of Hours in Adaptive Comfort Zone (%)	58%	81%	↑ 23%
3.	Peak Indoor Temperature on Hottest Day	37.1 °C	32.8 °C	↓ 4.3 °C
4.	AC Energy Consumption (March–Sept)	1672 kWh	1084 kWh	↓ 35%
5.	Payback Period for PCM Integration	–	~5.2 years	Based on Delhi utility rates

The results indicate that the bio-based PCM facade system significantly enhanced indoor thermal comfort by stabilizing temperatures near the PCM melting point during hot afternoons and releasing stored heat during cooler nights. This passive thermal buffering effect helped reduce dependency on mechanical cooling systems, particularly during the shoulder seasons when air conditioning was otherwise intermittently required.

Additionally, the adaptive comfort compliance increased by 23%, reflecting higher occupant satisfaction. The initial cost of PCM materials (INR ₹1,200–₹1,400 per m^2) was partially offset by lower cooling costs, and lifecycle carbon assessments suggest a 15–20% reduction in operational CO_2 emissions.

The inferences of this base case study are as follows:

1. Bio-PCM facades are well-suited for composite climates with large temperature swings.
2. Integration is feasible in both new construction and retrofit scenarios.
3. Proper melting point selection and night ventilation coupling are critical to achieving full thermal benefits.
4. Further gains could be realized by combining PCM walls with smart glazing or ventilated facade systems.

INNOVATIVE FACADE MATERIALS

Bio-based Composites and Hygrothermal Buffers

Bio-based composites (hemp-lime, wood fiber, mycelium-based panels) offer high moisture buffering capacity, reducing humidity-induced discomfort and indirectly lowering cooling demand by improving latent heat balance (Collet & Pretot, 2014). They also contribute to carbon sequestration, aligning envelope performance with embodied carbon reduction goals.

Fig. 4: Bio-based Composite Buffers

Building-Integrated Photovoltaics (BIPV) with Thermal Decoupling

Although primarily an energy-generation strategy, BIPV facades can be thermally decoupled from the indoor environment (ventilated PV double-skin), reducing solar gains on the inner wall while preheating air for domestic hot water or ventilation systems.

Fig. 5: Building-Integrated Photovoltaics (BIPV)

SYNTHESIZED RESULTS FROM THE LITERATURE

Meta-analyses of PCM-integrated envelopes indicate peak load reductions of 10–30% and annual HVAC energy savings of 5–20%, depending on climate, PCM set-point, and installation layer (internal vs. external) (Kuznik et al., 2011; Ascione et al., 2014; Soares et al., 2013). Adaptive comfort compliance improved by 10–30%, particularly in transitional seasons where PCM melting points align with shoulder-season temperatures.

Aerogel-based plasters achieved U-value reductions of 40–60% relative to conventional mineral wool at comparable thicknesses (Baetens et al., 2011). Electrochromic glazing studies showed 10–20% cooling energy savings and improved glare control, though winter penalties can arise if control strategies over-shade (Granqvist, 2014). VIP retrofits consistently delivered space-saving insulation with 20–50% heating energy reductions in cold and temperate climates, but their effective life strongly depends on edge-seal performance and installation care (Jelle, 2011).

Bio-based hygroscopic materials enhanced humidity buffering, with latent cooling effects indirectly reducing discomfort during high-humidity periods (Collet & Pretot, 2014). However, quantifying their contribution to operative temperature remains an open research front, necessitating coupled hygrothermal-comfort models.

CONCLUSION

Innovative facade materials present a decisive opportunity to redefine thermal comfort in residential buildings by transforming the envelope into an adaptive, high-performance system. Evidence suggests substantial reductions in thermal discomfort and mechanical energy demand when materials are carefully selected, integrated, and controlled. Future research should prioritize:

1. Multi-objective optimization frameworks coupling comfort, energy, daylight, embodied carbon, and cost.
2. Long-term durability datasets and standardized accelerated aging protocols for PCMs, VIPs, and electrochromics.
3. Hygrothermal-comfort coupling for bio-based materials to quantify latent comfort benefits.
4. Digital twins and AI-driven control to optimize dynamic facades in operation based on real-time indoor/outdoor sensing and occupant feedback.
5. Circularity and bio-based innovation, ensuring that performance gains do not come at the cost of end-of-life burdens.

By reframing facades as comfort engines rather than passive shells, residential architecture can move closer to resilient, low-carbon, and health-centered living environments.

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BORDER INFRASTRUCTURE FOR REGIONAL DEVELOPMENT LEVERAGING INTEGRATED CHECK POSTS FOR ECONOMIC INTEGRATION AND INCLUSIVE GROWTH IN INDIA'S REMOTE AREAS

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Abstract

This research examines how Integrated Check Posts (ICPs) can act as catalysts for regional development, economic integration, and inclusive public architecture in India's remote border areas, with particular focus on the Northeast. Through an analysis of the Sabroom Landport in Tripura, the study shows how border infrastructure can move beyond security and trade facilitation to become multimodal nodes of inclusive growth. Using a mixed-methods approach combining policy analysis, design evaluation, and comparative case studies, the findings reveal that inclusively designed ICPs can unlock local economic potential, enhance mobility, and create dignified civic spaces for marginalised populations. The study proposes a framework for future ICPs that aligns national strategic goals with local development needs, supporting India's vision of resilient and equitable border communities by 2047.

INTRODUCTION

India's border regions have long remained peripheral to development, constrained by isolation, weak connectivity, and underinvestment. As the nation approaches its 2047 centenary, integrating these areas has become a priority that links security, regional growth, and social inclusion. The Northeast—sharing 5,182 kilometres of borders with five countries—illustrates both the challenges and opportunities of this agenda.

While border infrastructure on security and trade, it is now viewed as a catalytic urban node connecting remote regions to wider networks of goods, people, and culture. Introduced after the Kargil War (1999), Integrated Check Posts (ICPs) embody this shift by consolidating customs, immigration, warehousing, and passenger services within single facilities.

This study shows that inclusively designed ICPs can achieve multiple objectives. The Sabroom ICP in Tripura—built at ₹250 crore on 49 acres—demonstrates how such projects can function as comprehensive terminals while strengthening connectivity and local development. The paper argues that ICPs must evolve beyond utilitarian roles into instruments of inclusion, commerce, and regional balance, contributing to discourse on inclusive public architecture and offering a framework that aligns national strategy with community aspirations.

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LITERATURE REVIEW

Evolution of Border Infrastructure in India

The conceptualisation of ICPs followed India's post-Kargil border management review, recognising the need for integrated facilities to handle growing trade and passenger flows. The Land Ports Authority of India (LPAI), established under the 2010 Act, has since developed nine operational ICPs that managed trade worth ₹95,488 crore in 2020–21, about 40% of India's trade with neighbours. Analysis by the Centre for Social and Economic Progress shows ICPs have streamlined flows through modernisation, though challenges remain in mirror infrastructure, public-private partnerships, and warehousing. Expansion to 24 ICPs by 2025 underscores their strategic role in connectivity.

Northeast India: Development Challenges and Opportunities

Northeast India's development is shaped by geographic isolation and historic marginalisation. Despite its location as a gateway to Southeast Asia, the region contributes only 2.8% to India's GDP, with 3.1% of the population. Challenges include limited connectivity, reliance on the narrow Siliguri Corridor, and inadequate infrastructure. Government interventions such as NESIDS, BADP, and the Act East Policy aim to bridge these gaps. Between 2021 and 25, NESIDS sanctioned 90 projects worth ₹3,417.68 crore, while BADP covers 456 blocks

across 16 states and two union territories, including 148 in the Northeast.

Inclusive Design in Public Infrastructure

Inclusive design has gained traction through initiatives such as NIUA's BASIIC program, which integrates universal design into urban planning for accessibility across all user groups. The 2021 Harmonised Guidelines for Universal Accessibility, developed under the UNCRPD 2007 and the Rights of Persons with Disabilities Act 2016, set standards for barrier-free environments and seamless travel chains. Case studies such as the Sugamya Kashi project in Varanasi demonstrate practical application, with universal design, multilingual signage, and community participation improving accessibility in historic contexts.

International Best Practices in Cross-Border Infrastructure

Global experiences highlight success factors such as institutional capacity, coordinated bilateral planning, stakeholder engagement, and governance. Nordic initiatives like NORDINFRA emphasise systemic coordination and joint economic analysis, with the Ø resund Link between Denmark and Sweden showcasing integrated cross-border mobility. Similarly, USA–Mexico and Norway–Sweden cooperation stresses mirror infrastructure, harmonised procedures, and community engagement. These models reinforce the importance of gender sensitivity, human rights compliance, and regional collaboration in border management.

Research Gaps and Contributions

Existing literature primarily emphasises border security and trade facilitation, with limited focus on inclusive design and regional development. Few studies assess socio-economic impacts or community integration potential. This research addresses that gap by positioning ICPs as instruments of inclusive regional development, showing how design and planning can align infrastructure with multiple objectives while enhancing dignity and social inclusion.

THEORETICAL FRAMEWORK

Border Infrastructure as Catalytic Urban Nodes

This research conceptualises border infrastructure as catalytic urban nodes capable of driving regional development. Drawing from urban planning theory, such projects generate impacts beyond their immediate scope, acting as growth poles that attract investment, create employment, and stimulate ancillary activities. Three principles underpin this view: multimodal integration, where ICPs function as transport and logistics hubs, reducing costs and enhancing connectivity; economic clustering, where concentrated border functions encourage private investment in logistics, warehousing, and services; and social infrastructure, where civic and community facilities transform ICPs into dignified public spaces serving both travellers and locals.

Inclusive Public Architecture Framework

The study applies the inclusive public architecture framework shaped by India's BASIIC program and NIUA guidelines. It emphasises physical accessibility through universal design and signage; social inclusivity via gender-sensitive and culturally sensitive spaces; economic accessibility through affordable services and local job creation; and cultural appropriateness by embedding local identity in functional design.

Regional Development Integration Model

A regional development integration model frames how border infrastructure aligns with broader strategies. It highlights connectivity enhancement, both physical and digital; economic diversification through tourism, logistics, and services; social integration by linking border communities with mainstream development; and environmental sustainability, ensuring infrastructure contributes positively to long-term regional goals.

RESEARCH METHODOLOGY

Research Design

This study adopts a mixed-methods qualitative approach combining documentary analysis, case study methodology, and comparative assessment. The design addresses the complexity of border infrastructure while maintaining analytical rigour and policy relevance. Three analytical levels are employed: macro-level analysis of national policy frameworks and institutional arrangements; meso-level assessment of Northeast India's development challenges and opportunities; and micro-level examination of the Sabroom ICP's design, operations, and local impacts.

Data Sources and Collection

A multi-source data strategy was applied. Primary sources included policy documents and reports from the LPAI, Ministry of Home Affairs, and MDoNER,

as well as official statistics and planning documents for the Sabroom ICP. Secondary sources comprised academic studies, think tank reports (CSEP, ORF, CUTS), and international case comparisons. Tertiary sources such as media coverage, technical reports, and feasibility studies supplemented the analysis, providing context and triangulation.

Analytical Framework

The framework evaluates ICPs through four dimensions: design and planning, focusing on spatial organisation and integration with regional strategies; inclusive architecture, assessing universal accessibility and user needs; regional development impact, measuring economic, social, and infrastructure outcomes; and cross-border connectivity, analysing trade facilitation and regional integration effectiveness.

Case Study Selection and Rationale

Sabroom ICP was selected for its strategic, regional, and developmental significance. As India's newest and most comprehensive ICP, it reflects contemporary design principles and advanced facilities. Its location near Chittagong port and integration with the Maitri Setu bridge highlight its role as a critical connectivity node for Northeast India. Moreover, robust documentation of its planning and implementation provided a strong empirical base for analysis.

Limitations and Mitigation Strategies

The study recognises limitations. Sabroom's recent completion restricts long-term impact assessment, mitigated by reference to other ICPs and comparable development patterns. Direct field observation was not feasible; hence, secondary sources and expert inputs were used. Limited Indian comparators were addressed through international best practice analysis adapted to local conditions.

CASE STUDY: INTEGRATED CHECK POST, SABROOM

Project Overview and Strategic Context

The Sabroom ICP in South Tripura's Gomati district represents a new generation of border infrastructure designed to serve multiple development objectives. Built at a cost of ₹250 crore and spanning 49 acres, it is among India's most comprehensive border facilities. Beyond its scale, the project plays a strategic role in advancing India's Act East Policy, positioning the Northeast as a gateway to Southeast Asia. Prime Minister Narendra Modi laid the foundation stone in March 2021, highlighting its significance for trade and connectivity with Bangladesh. The ICP's adjacency to the 1.9 km Maitri Setu bridge linking Sabroom with Ramgarh in Bangladesh creates an integrated cross-border corridor.

Design Features and Inclusive Architecture

Sabroom ICP embodies inclusive design principles within a modern logistics and processing hub. Customs, immigration, warehousing, and container transhipment are integrated within a single user-friendly facility. The layout applies universal design standards with wide corridors, barrier-free access, and multilingual signage to ensure usability for diverse travellers. Gender inclusivity is addressed through separate waiting areas, restrooms, and security facilities for women, reflecting LPAI's three-year target of gender-friendly ICPs. Community integration is also evident in shared amenities such as parking, commercial spaces, and civic facilities that benefit both travellers and residents.

Economic Integration and Connectivity Impact

Strategically, Sabroom provides Northeast India direct access to Chittagong port, just 75–80 km away, compared to 1,700 km to Kolkata/Haldia ports, generating significant cost and time savings. Its future linkage to Bangladesh's Matarbari deep-sea port (100 km away) will further strengthen its role as a regional trade hub. Designed for multimodal integration, the ICP connects directly to Maitri Setu and is planned for future railway and waterway connectivity. These facilities support local employment and entrepreneurship in logistics, warehousing, and transportation while accommodating future trade growth.

Cross-Border Cooperation and Bilateral Relations

The project exemplifies bilateral cooperation, with India and Bangladesh developing complementary facilities at Sabroom and Ramgarh. Although political factors delayed the 2024 inauguration to early 2025, both governments remain committed. Beyond bilateral trade, Sabroom reduces Northeast India's dependence on the narrow Siliguri Corridor, enhancing resilience and regional integration.

Challenges and Implementation Considerations

The ICP's effectiveness depends on supporting infrastructure such as approach roads, utilities, and digital integration. Capacity building is also essential, requiring trained personnel to manage customs, immigration, and logistics. Ensuring

equitable community benefits will require proactive stakeholder engagement and development programs that strengthen local participation.

Comparative Analysis with Other ICPs

Compared to earlier ICPs like Petrapole-Benapole (2016) and Agartala (2013), Sabroom represents a more advanced model, integrating lessons from past projects. Its scale and inclusivity mark a clear evolution in India's border infrastructure. Designed to accommodate digital initiatives such as single-window clearance and electronic data interchange, Sabroom positions itself within India's broader digitalisation drive. Overall, the project demonstrates how border facilities can simultaneously serve security, trade, and community objectives, offering valuable lessons for future ICP development.

ANALYSIS AND DISCUSSION

ICPs as Instruments of Inclusive Regional Development

ICPs designed with inclusivity can act as catalysts for economic, social, and spatial transformation. The Sabroom case illustrates this through its 49-acre integrated design, combining customs, logistics, warehousing, and commercial functions that generate jobs and entrepreneurship. Its location near Chittagong port (75–80 km vs. 1,700 km to Kolkata) offers significant cost advantages that could reshape Northeast India's trade geography. Inclusive design further transforms ICPs into civic spaces: Sabroom's barrier-free access, gender-sensitive facilities, multilingual signage, and community amenities enhance user experience and improve local relations.

Integration of Regional Development and Policy Alignment

ICPs align with India's Act East Policy and integrate with schemes such as NESIDS (₹3,417.68 crore), PM-DevINE (₹1,500 crore), and BADP (456 blocks). Yet, stronger regional and local coordination is needed to ensure benefits reach nearby communities. Large-scale infrastructure investments—₹1.07 lakh crore in highways and 10 new airports—create supportive conditions. Sabroom's links to Maitri Setu and future railways highlight the need to embed ICPs in wider connectivity networks rather than treat them as standalone facilities.

Inclusive Design Implementation and Universal Accessibility

Sabroom demonstrates progress in universal accessibility with barrier-free design, wide corridors, and gender-sensitive facilities. However, greater community participation is needed to ensure cultural appropriateness and ownership. LPAI's plan to make all ICPs gender-friendly within three years is notable, but inclusivity must extend beyond physical design to staff training, operational practices, and community engagement.

International Best Practices and Comparative Analysis

Comparisons reveal alignment with but also gaps from global standards. Nordic models emphasise joint planning and systemic coordination, while the USA–Mexico system highlights community engagement. EU approaches stress mirror infrastructure and harmonised procedures, where India shows mixed progress. Global experience also underscores digital integration: while Sabroom has digital provisions, broader adoption of single-window clearances and real-time data sharing is needed.

Challenges and Implementation Considerations

Effective ICPs require coordination across multiple agencies—customs, immigration, border security, and development authorities. Current mechanisms need strengthening through capacity building, logistics expertise, digital systems skills, and knowledge sharing. Sustainability is another challenge: despite ₹250 crore investment, long-term success depends on maintenance, adaptive management, and community involvement. Monitoring must track both operational efficiency (trade volumes, processing times, satisfaction) and development outcomes (employment, welfare, connectivity).

PROPOSED FRAMEWORK FOR INCLUSIVE BORDER INFRASTRUCTURE

Integrated Planning and Design Framework

The framework builds on lessons from Sabroom ICP, global practices, and inclusive design principles to create a replicable model for future projects. It emphasises a multi-scalar approach that aligns national policies such as the Act East Policy with regional connectivity and state development plans, while addressing local priorities and cultural contexts. Inclusive design standards span four dimensions: physical accessibility through universal, barrier-free design; social inclusivity via gender-sensitive and culturally appropriate facilities; economic accessibility through affordable services, local jobs,

and SME support; and environmental sustainability through climate-responsive design and efficient resource use.

Stakeholder Engagement and Community Participation

Effective ICP development requires engagement across government agencies, private sector actors, civil society, and international partners. The private sector strengthens logistics and trade functions, while civil society and academia ensure local perspectives. Community ownership is vital, supported by consultation, local employment, entrepreneurship opportunities, benefit-sharing mechanisms, and continuous feedback systems to maintain responsiveness.

Economic Integration and Development Catalysis

ICPs should catalyse diversified growth beyond trade, functioning as logistics hubs, tourism nodes, sites for border manufacturing, and enablers of digital services. Strong local linkages are essential, including procurement from local suppliers, SME support, skills training, and expanded markets for regional products, ensuring communities directly benefit from connectivity.

Governance and Institutional Framework

The framework proposes an integrated governance structure with a strategic oversight committee for national and international coordination, an operational management board for daily functions, technical working groups for specialised tasks, and a community advisory panel for local representation. Monitoring systems should assess performance across four dimensions: operational efficiency (trade volumes, processing times, user satisfaction), development outcomes (employment, income, infrastructure), inclusion (accessibility, gender equity, marginalised participation), and sustainability (environmental impact, long-term viability).

Implementation Strategy and Phased Development

Implementation should follow phased development: Phase 1 establishes core inclusive facilities; Phase 2 enhances community integration and economic components; Phase 3 incorporates advanced technologies and connectivity; and Phase 4 replicates and scales the model to other borders. Capacity building and knowledge management remain central, with specialised training for border personnel, local entrepreneurship support, and systematic documentation of lessons learned. International cooperation and learning exchanges further strengthen sustainability and innovation.

CONCLUSION

This research shows that Integrated Check Posts (ICPs), when inclusively designed, can act as catalysts for regional development, economic integration, and social inclusion. The Sabroom ICP case study, situated within Northeast India's development context and informed by global practices, illustrates transformative potential well beyond traditional security and trade functions.

Key Research Findings

ICPs can operate as multifunctional nodes with economic, social, and spatial impacts. Sabroom's 49-acre layout, proximity to Chittagong port, and integrated facilities demonstrate their ability to reshape regional trade geography while advancing national goals. Progress in accessibility, gender-sensitive facilities, and community features is evident, though greater participation and cultural alignment are needed. Policy integration with the Act East Policy, NESIDS, PM-DevINE, and BADP shows strong national coordination. International comparisons, especially Nordic and EU models, highlight opportunities for joint planning and community engagement.

Theoretical and Practical Contributions

The study contributes a framework that positions border infrastructure as instruments of inclusive regional development, combining catalytic urban node theory, inclusive design, and regional integration. Practically, it provides policymakers and planners with guidance on multi-scalar planning, stakeholder engagement, and phased implementation to improve ICP effectiveness.

Policy Recommendations

Immediate (1–2 years): Mandate inclusive design, institutionalise community engagement and monitoring, and strengthen inter-agency coordination.

Medium-term (3–5 years): Scale inclusive design across ICPs, expand digital integration, deepen cooperation with neighbours, and build specialised training programs.

Long-term (5–10 years): Position ICPs as anchors of regional development zones and establish centres of excellence and regional cooperation frameworks.

Future Research Directions

Further study is needed on long-term development impacts of inclusive ICPs; advanced technologies such as AI, block chain, and IoT; comparative models of cross-border cooperation; and climate-resilient, sustainable design strategies.

Limitations and Future Considerations

The study relies mainly on secondary sources, with limited field data, and Sabroom's recent completion restricts long-term impact assessment. Implementation faces capacity, coordination, and resource challenges, requiring sustained commitment. Moreover, the framework must be adapted carefully to varied geographic, cultural, and institutional contexts.

Final Reflections

As India approaches 2047, inclusive and connected border communities are both strategic priorities and moral responsibilities. ICPs represent progress from basic checkpoints to multimodal hubs, but their success depends on innovation, participation, and international cooperation. The Sabroom ICP exemplifies how border infrastructure can integrate commerce, security, and community, turning peripheral regions into gateways of opportunity and offering a model for global cross-border development.

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MITIGATING URBAN HEAT IN INDIAN CITIES: A SYNERGISTIC APPROACH TO URBAN BIODIVERSITY, BLUE-GREEN INFRASTRUCTURE AND NET-ZERO COOLING FOR VIKSIT BHARAT 2047

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Abstract

India's urban centers face intensifying Urban Heat Island (UHI) effects, necessitating innovative cooling policies and sustainable urban planning to achieve resilient, low-carbon cities by 2047. This paper explores urban biodiversity, blue-green infrastructure (BGI), and net-zero cooling strategies to mitigate urban heat. Urban biodiversity, through green corridors and urban forests, enhances thermal regulation and ecological resilience. BGI, incorporating green roofs, reflective pavements, and revitalized urban water bodies, reduces ambient temperatures while improving stormwater management. Net-zero cooling strategies integrate passive architectural design, energy-efficient cooling technologies, and renewable energy systems to minimize carbon emissions. Despite challenges like land scarcity, high implementation costs, and policy gaps, opportunities arise from government initiatives and advancements in technologies such as cool roofing and smart ventilation systems. Drawing on case studies and innovative practices, this paper proposes a comprehensive urban planning framework that synergizes biodiversity, BGI, and net-zero approaches to combat urban heat, contributing to India's climate adaptation goals and enhanced urban livability.

INTRODUCTION

India's rapidly urbanizing cities are increasingly affected by the Urban Heat Island (UHI) effect, where urban areas experience significantly higher temperatures—often 1–7°C hotter, and sometimes up to 10–15°C more—than their rural surroundings. This is driven by dense construction using heat-retaining materials like asphalt and concrete, reduced green and blue spaces, and emissions from buildings, vehicles, and industry.

UHI intensifies energy demand for cooling, worsens air pollution, and poses severe public health risks, particularly for vulnerable populations. For example, Delhi records UHI intensities ranging from 0.9–5.9°C, and surface temperatures in several cities can exceed 50°C. Urban expansion has led to a 47.7% reduction in green spaces and 42.9% in water bodies across major cities as per CSE studies (CSE & Sareen, 2025).

While traditional Indian architecture used climate-responsive designs to mitigate heat, contemporary planning must now integrate urban biodiversity, blue-green infrastructure (BGI), and net-zero cooling strategies to sustainably manage urban temperatures and enhance liveability.

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URBAN BIODIVERSITY AND BLUE-GREEN INFRASTRUCTURE FOR THERMAL REGULATION

Urban Biodiversity and Vegetation Strategies

Urban biodiversity—comprising urban forests, green corridors, and native vegetation—mitigates Urban Heat Island (UHI) effects by providing shade, reducing surface heat, and enhancing evapotranspiration. Initiatives like Miyawaki forests and pocket parks in cities such as Pune and Bengaluru have demonstrated measurable cooling impacts. Despite constraints like land scarcity and maintenance demands, community initiatives and public-private partnerships are effective enablers.

Blue-Green Infrastructure (BGI)

BGI integrates vegetated and water-based systems—green roofs, wetlands, ponds, lakes, reflective pavements, and permeable surfaces—to cool urban environments and improve water management. Revived water bodies, like the Sabarmati Riverfront and Chennai's lakes, have lowered nearby air temperatures by up to 4–5°C. Broader BGI benefits include temperature reductions ranging from 2.8°C to 12.6°C, with street trees reducing surface heat by up to 7.6°C, and green roofs by up to 0.9°C (Kumar, 2024, #). Permeable surfaces allow water infiltration and

reduce heat retention, while blue features like ponds and lakes act as large thermal sinks, though they present design challenges in humid climates.

Climate-Responsive Urban Design and Architecture

Traditional Indian design leveraged passive cooling using materials, colors, and layouts adapted to local climates. Modern retrofits—cool roofs, vertical gardens, shaded streets, and green facades—help reduce indoor and ambient heat. Building form and envelope influence thermal performance:

- Orientation: North-South facing buildings experience less solar gain.
- Aspect Ratio: Taller buildings with narrow spacing enhance shading but may trap heat.
- Envelope & Materials: Low U-value (better insulation), insulated roofs, and reflective coatings reduce heat ingress.
- Window Design: Strategic shading, lower SHGC (Solar Heat Gain Coefficient), and controlled WWR (Window-to-Wall Ratio) minimize solar heat gain.
- Buffer Zones: Placing service areas on heat-exposed facades reduces heat transfer to living spaces.

Net-zero cooling strategies

Net-zero cooling strategies represent a transformative pathway for Indian cities to decouple rising cooling demand from increasing carbon emissions. This involves a tripartite approach: minimizing cooling loads through passive design (e.g., orientation, shading, thermal insulation), maximizing system efficiency using high-performance appliances and building envelopes, and offsetting remaining energy demand with onsite or grid-connected renewable energy sources like rooftop solar PV. Additionally, integrating thermal comfort metrics in urban design codes and expanding access to district cooling systems can ensure equitable and scalable adoption. Such strategies not only reduce operational energy but also enhance indoor health and productivity outcomes, contributing to inclusive urban resilience.

Together, biodiversity enhancement, BGI, climate-conscious design and net zero cooling strategies form a synergistic strategy for mitigating UHI effects and building thermally resilient cities.

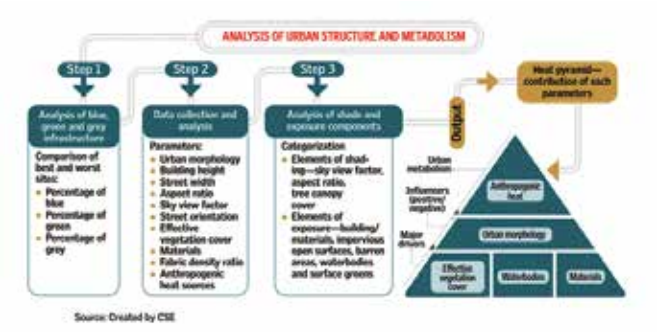
STRUCTURED METHODOLOGY FOR URBAN HEAT ASSESSMENT AND MITIGATION

The structured methodology for urban heat assessment and mitigation offers a data-driven, replicable approach to tackling extreme heat in cities. It begins with mapping Land Surface Temperature (LST) using Lands at satellite data and GIS software, applying formulas to delineate heat-prone zones and detect persistent or emerging urban heat islands (UHIs). Heat centres are then identified by isolating zones that exceed IMD thresholds (e.g., >45°C for plains) and validating patterns with multi-year data. The methodology then analyzes urban morphology, focusing on parameters like built density, aspect ratio, building height, street orientation, and Sky View Factor (SVF) to evaluate how built form affects heat retention and airflow—distinguishing between typologies like compact mid-rise or open low-rise. Parallelly, blue-green infrastructure (BGI) is mapped using NDVI and NDWI indices to quantify cooling benefits from vegetation and water bodies, highlighting “cooling gaps” in the urban fabric. This is followed by calculating a Heat Vulnerability Index (HVI), integrating exposure (LST and heat frequency), sensitivity (demographics such as elderly, slum dwellers, outdoor workers), and adaptive capacity (access to water, power, health care) to prioritize high-risk zones like informal settlements with low resilience. A material audit assesses heat-absorbing construction surfaces—such as tin roofs or asphalt paving—and promotes alternatives like cool roofs , green façades, and permeable pavements. Finally, zoning recommendations advocate for land-use regulations mandating shaded corridors, minimum green cover, reflective materials, and designated retrofit overlays in vulnerable wards. This integrated approach—merging remote sensing, urban form diagnostics, material science, and social vulnerability mapping—empowers cities to monitor heat precisely, identify at-risk populations, and deploy targeted, equitable, and climate-responsive urban cooling strategies through their master plans.

THE HEAT MITIGATION PYRAMID

Urban cooling strategies operate across three interconnected tiers of impact. At the base, blue-green infrastructure offers the most sustained and significant cooling benefits—parks, tree-lined streets, wetlands, and restored water bodies can lower ambient temperatures by 7–10°C, creating long-term microclimatic stability. In the middle layer, urban morphology and materials play a

critical moderating role; well-planned layouts, optimal building orientation, and the use of reflective or permeable materials enhance shading, airflow, and thermal dissipation. When applied effectively, such design interventions can reduce land surface temperatures by up to 8°C. At the peak, urban metabolism—comprising anthropogenic heat emissions from air-conditioning units, vehicles, and industrial processes—further elevates urban heat stress. While its impact is supplementary, targeted measures like passive cooling techniques, promoting clean mobility, and limiting fossil fuel use are essential to mitigate this layer of heat burden and reinforce systemic cooling.



POLICY INITIATIVES AND FUNDING PROGRAMS FOR URBAN HEAT MITIGATION

India's response to the escalating Urban Heat Island (UHI) phenomenon has evolved through a combination of national missions, localized zoning tools, building regulations, and community-driven models. These policy instruments not only guide investments and urban form but also shape institutional behaviors and public participation. A multi-pronged approach—integrating ecological, architectural, and technological pathways—is gradually taking shape, with varying levels of success across Indian cities.

National Missions: Smart Cities and AMRUT

The Smart Cities Mission and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) represent the Government of India's flagship efforts to promote sustainable and resilient urban development. These programs provide both strategic direction and capital funding to enable climate-sensitive interventions.

- **Cool Roof Programs:** Many Smart Cities have initiated large-scale deployment of reflective roofing materials, particularly in slum rehabilitation and low-income housing, to reduce indoor heat stress. Cities like Hyderabad and Ahmedabad have adopted city-wide cool roof policies under these missions.
- **Blue-Green Infrastructure (BGI):** Urban forests, city parks, rejuvenated lakes, and bio-retention landscapes have been developed as part of AMRUT's green space targets. These BGI elements function as urban thermal regulators while improving groundwater recharge and stormwater buffering.
- **Stormwater Management and SuDS:** Several projects under AMRUT integrate Sustainable Urban Drainage Systems (SuDS) to manage surface runoff while contributing to passive cooling through water-sensitive urban design.

  Impact: While the missions have fostered innovation and demonstrative best practices, their effectiveness varies by city capacity and vision. Limited convergence with building codes and weak integration with urban climate data remain constraints to holistic implementation.

Local Climate Zone (LCZ) Mapping

LCZ classification offers a scientifically validated framework to assess microclimatic variation across urban typologies based on land cover, built form, and thermal behavior. Unlike generic land-use classifications, LCZ maps distinguish zones like compact mid-rise, open low-rise, and heavy industry—each with unique thermal signatures.

- Kolkata used LCZ mapping to identify UHI hotspots and prioritize tree plantation and reflective paving.
- Delhi leveraged LCZ data to guide material choices in dense neighborhoods.
- Kamrup (Assam) integrated LCZ findings into regional climate adaptation strategies.

Benefits:

- Enables targeted urban cooling strategies at the neighborhood scale.
- Supports micro-level zoning reform, such as mandatory shading in heat-intensive corridors.
- Optimizes land resource allocation by balancing densification with cooling requirements.

However, LCZ adoption in India is still limited to pilot projects and academic collaborations. Institutional

mainstreaming of this tool into municipal decision-making remains a critical next step.

Community-Led and Public–Private Partnership (PPP) Models

Heat resilience efforts gain traction and sustainability when communities and private actors are co-owners of urban cooling solutions.

- Indore's "Green Guardians": A civic engagement initiative mobilizing residents to plant and maintain urban trees, improving neighborhood-level microclimates and instilling a sense of environmental stewardship.
- Delhi Biodiversity Parks: Jointly developed by DDA and CEMDE, these parks transform degraded lands into biodiverse, thermally regulated ecosystems using a science-citizen-government collaborative model.

Analytical Insight:

- These initiatives exemplify the power of decentralized action and low-cost interventions in high-stress zones.
- PPPs can unlock innovative financing, improve project efficiency, and scale up climate infrastructure through risk-sharing and technical expertise.
- Their success depends on robust community engagement, long-term O&M frameworks, and alignment with municipal policies.

Heat Action Plans (HAPs)

Heat Action Plans serve as the first line of defense against extreme heat events, combining health, infrastructure, and behavioral responses.

- Early Warning Systems: Use of IMD forecasts and heat alerts to guide public response.
- Emergency Measures: Deployment of cooling shelters, water kiosks, and adjusted work hours.
- Community Outreach: Risk communication targeting slum populations, children, elderly, and outdoor workers.
- Long-Term Urban Interventions: Integration of cool roofing, green shading, and BGI into master plans.
- Capacity Building: Training city staff, health professionals, and planners for preparedness and response.

Examples:

- Ahmedabad (2013) pioneered India's first HAP, which is now internationally recognized for its impact in reducing heat-related mortality.
- Delhi, Nagpur, and Kolkata have since adopted and refined the model with spatial vulnerability mapping and multi-agency coordination.

Gap: While HAPs have improved emergency preparedness, many remain underfunded, lack integration with spatial planning, or are inactive between heat seasons. A stronger legislative mandate and monitoring mechanism could enhance their continuity and effectiveness.

Energy Conservation and Sustainable Building Code (ECSBC)

The ECSBC, developed by the Bureau of Energy Efficiency (BEE), provides a regulatory framework for thermally efficient, energy-saving buildings—critical to reducing urban cooling loads.

- Encourages passive cooling strategies, including optimal building orientation, shading devices, and high-albedo surfaces.
- Sets thermal performance benchmarks for walls, fenestration, and roofing to reduce heat ingress.
- Promotes renewable energy integration, particularly solar PV and solar-assisted cooling.

Current Status: Adoption of ECSBC is currently voluntary in most states, with limited enforcement at the municipal level. Integration into local building bye-laws and greater emphasis on affordable housing sectors are needed for broader impact.

Policy Landscape for Urban Heat Mitigation in India

Policy / Program	Implementing Agency	Key Cooling Components	Coverage	Gaps / Limitations
Smart Cities Mission	Ministry of Housing & Urban Affairs	Urban greenery, open spaces, climate-resilient infrastructure	100 cities	Heat mitigation not a primary metric; cooling impact not always measured
AMRUT 2.0	Ministry of Housing & Urban Affairs	Urban water bodies, stormwater reuse, green cover enhancement	500+ cities	Limited convergence with biodiversity or building-scale cooling
National Action Plan on Climate Change (NAPCC) – SAPCCs	Ministry of Environment, Forest and Climate Change	State-level cooling policies under climate resilience mandates	All states	Variable depth and quality; often weak urban focus
Energy Conservation Building Code (ECBC) & Eco-Niwas Samhita (ENS)	Bureau of Energy Efficiency (BEE)	Building envelope efficiency, daylighting, thermal comfort	Commercial & residential	Poor compliance in many states; limited linkage with urban planning
Heat Action Plans (HAPs)	State and City Governments	Early warning systems, cool roof programs, public outreach	20+ cities	Design interventions minimal; variable update and enforcement status
Urban Greening Guidelines 2014	Ministry of Urban Development	Tree planting, native species promotion, green buffers	Advisory for cities	No mandatory provisions or enforcement mechanisms
State Climate Missions / Cool Roof Initiatives	State Governments / NGOs	Reflective roof subsidies, awareness programs	Telangana, Gujarat, etc.	Often unscalable or underfunded; insufficient monitoring

Together, these policy instruments—ranging from national missions to local zoning tools, building codes, and participatory models—create a robust foundation for climate-adaptive, heat-resilient urban development in India. Their coordinated application ensures that mitigation efforts are not only technically sound and resource-efficient, but also inclusive and scalable.

RECOMMENDATIONS

Holistic Urban Planning and Climate-Sensitive Design

To effectively mitigate urban heat, Indian cities must embed ecological resilience into their foundational planning:

- Mainstream urban biodiversity and Blue-Green Infrastructure (BGI) into city master plans, zoning regulations, and urban design guidelines. This includes the creation of urban forests, restoration of wetlands, and development of interconnected green corridors.
- Adopt climate-responsive architectural practices by mandating passive design principles, use of cool roofs, reflective pavements, and thermally efficient building materials in both new construction and retrofits.
- Prioritize spatial layouts that enhance natural ventilation, shade, and heat dissipation—especially in vulnerable, high-density urban zones.

Policy Integration and Institutional Strengthening

Robust governance mechanisms are essential to scale and sustain urban heat mitigation efforts:

- Strengthen and expand the Energy Conservation and Sustainable Building Code (ECSBC) to mandate thermal comfort, passive cooling, and renewable integration across all building typologies.
- Utilize Local Climate Zone (LCZ) mapping as a planning tool to identify heat hotspots at a granular scale, guiding site-specific interventions like green buffers, reflective surfacing, or targeted shading structures.
- Encourage interdepartmental coordination between urban development, environment, and health agencies to implement unified heat resilience strategies.

Community Engagement and Public–Private Partnerships (PPP)

Equity and scalability in urban cooling efforts require bottom-up and collaborative approaches:

- Empower local communities through participatory projects such as Indore's "Green Guardians," involving citizens in planting, maintaining, and monitoring neighborhood green cover.
- Foster Public–Private Partnerships (PPPs) to mobilize investments in green and climate-resilient infrastructure. PPP models can leverage private innovation and funding while ensuring public access and impact.
- Offer incentives and green bonds for developers who incorporate BGI and passive cooling techniques in affordable housing and urban renewal projects.

Operationalization of Heat Action Plans (HAPs)

HAPs must evolve beyond emergency protocols into proactive urban management tools:

- Regularly update and institutionalize Heat Action Plans tailored to local geographies and demographics, ensuring integration into annual city planning cycles.
- Deploy early warning systems and real-time temperature dashboards, particularly for at-risk populations such as the elderly, construction workers, and informal settlements.
- Set up decentralized cooling centers, shaded public spaces, and hydration stations, especially during peak summer months, to reduce heat-related health risks.

Capacity Building and Adoption of Technology

Technology and skill development are critical enablers of urban heat resilience:

- Invest in remote sensing, GIS-based urban heat mapping, and thermal audits to identify priority zones and monitor the effectiveness of interventions.
- Promote smart cooling technologies, including solar-powered ventilation, radiant cooling systems, and demand-side energy management tools to reduce the carbon footprint of urban cooling.
- Build institutional capacity by training urban planners, engineers, and municipal staff on thermal comfort principles and climate-resilient urban design.

CONCLUSION

Effectively mitigating urban heat requires a multi-dimensional strategy that integrates ecological restoration, climate-responsive design, robust policies, and empowered local communities. Urban biodiversity and blue-green infrastructure form the ecological backbone of this response, creating resilient microclimates and enhancing thermal comfort through evapotranspiration and shading. At the same time, climate-smart building design and net-zero cooling technologies ensure that energy demands for cooling are reduced, aligning environmental and economic goals.

This paper proposes a holistic framework grounded in spatial analytics, planning reform, and participatory governance. It emphasizes the urgent need to mainstream localized interventions—such as LCZ-informed zoning, ECSBC-compliant buildings, and context-specific Heat Action Plans—within city development agendas. Institutional capacity building, public-private partnerships, and technology adoption must accelerate to ensure that urban heat mitigation efforts are not ad hoc but embedded in long-term urban strategies.

By drawing from successful case examples and synthesizing cross-disciplinary knowledge, Indian cities can turn the challenge of rising urban heat into an opportunity for innovation. Achieving thermal resilience is not only critical for public health and

livability but also central to realizing the aspirations of Viksit Bharat 2047—a future of equitable, sustainable, and climate-smart urbanization.

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RECLAIMING NEGLECTED URBAN FRAGMENTS: SCALABLE STRATEGIES FOR INCLUSIVE AND SUSTAINABLE INFRASTRUCTURE IN VIKSIT BHARAT 2047

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Abstract

As India looks toward its centenary in 2047, urban areas will face unprecedented challengesfrom spatial fragmentation and land scarcity to social exclusion and environmental degradation. Among these, the presence of neglected urban fragmentsoften formed due to outdated planning, infrastructural transitions, or failed developmentswill remain a persistent issue. However, these underutilized spaces will also offer significant opportunities for inclusive, sustainable development if approached strategically.

This paper will investigate how such urban fragments can be transformed into valuable community assets through scalable strategies that span both temporary (e.g., tactical urbanism) and permanent (e.g., adaptive reuse, compact mixed-use) interventions. It will assess the role of participatory planning, localized innovation, and contextual design in overcoming urban constraints and unlocking spatial potential. Drawing from case studies in Indian cities and international precedents, the study will highlight frameworks that support cost-effective, people-centric development at the micro scale.

By addressing the challenges and opportunities inherent in these forgotten spaces, the research will propose actionable approaches that align with India's urban missionssuch as the Smart Cities Mission and AMRUT 2.0and contribute directly to the goals of Viksit Bharat 2047. Ultimately, it will advocate for a regenerative urban model where even the smallest voids are reimagined as catalysts for transformation, equity, and resilience in Indian cities.

INTRODUCTION

India's cities are at a turning point. In 2021, the urban population was about 432 million; by 2047, it could reach 820 million. Much of this growth won't be in metros but in Tier II and III cities there are smaller places now emerging as economic hubs. This shift raises concerns: are these cities prepared for the pressure of jobs, housing and infrastructure.[1]

Urban regions already drive nearly 70% of GDP, a reminder of how central they are to India's future. Yet, economic output doesn't automatically create livable or sustainable cities. The Viksit Bharat 2047 vision are built on the pillars of youth, women, farmers, and the poor who puts urban transformation at the core of national progress. Though, the gap is massive: almost 70% of the infrastructure India will need by 2047 doesn't exist yet. That's alarming, but also an opening. If done wisely, it's a rare chance to build cities that are resilient, fair, and future-ready.[2]

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Defining Neglected Urban Fragments: Characteristics and Manifestations in Indian Cities:

India's fast-growing cities face a recurring issue of the scattered presence of neglected urban fragments. These pockets emerge when plans fade, projects stall, or infrastructure shifts. Some lie abandoned, others decay, many simply lose social

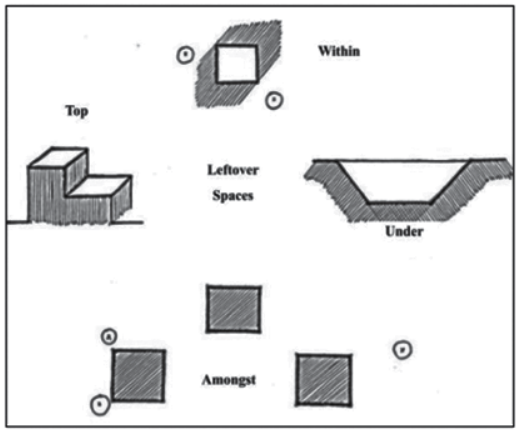

Fig 1: Type of Leftover Spaces in City Inside and Outside of a Built Structure

(Top of a Built Structure, Under a Built Structure and Around/Amongst/In-Between Built Structures)[27]

Fig. 2: Ber Sarai flyover looks like an ill-maintained, open-air shelter home (Sanchit Khanna/ HTPhotos)[27]

or economic use. At first, they seem minor; however, they weaken the urban fabric and waste land that could serve community life. The signs are clear: crumbling monuments, encroached plots, missing footpaths, overloaded transport, illegal parking, and open spaces casually taken over from that a pattern that raises serious concerns for urban futures , such spaces can be categorized which is shown in Fig 1 and Fig 2 show the real world depiction of such spaces .

Even when neglected, these fragments hold potential. With foresight, they could fuel inclusive growth. For instance, an abandoned plot might become a park or market. In practice, reclaiming them upgrades daily life and this can be easily studied by the interlinking connection as shown in fig 3. Ignoring them, however, leaves cities wasting land they can't afford to lose.

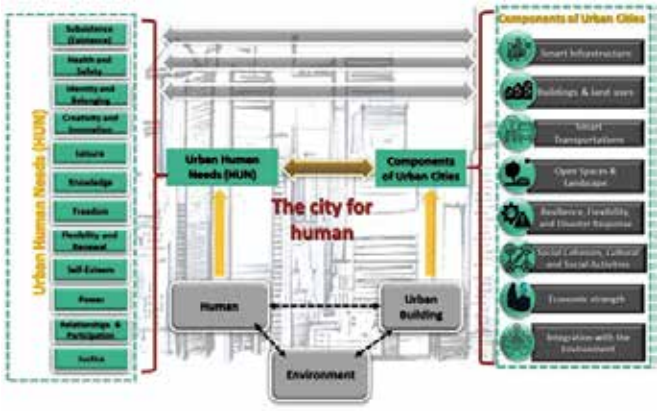

Fig. 3: Illustrating the concept of feedback between the human needs of the city and the components of the city[28]

Reclaiming neglected urban spaces can reshape city life, it favours regenerative infill by using land efficiently, saving resources, and strengthening urban sustainability.

CHALLENGES POSED BY NEGLECTED URBAN FRAGMENTS IN INDIA

Spatial Fragmentation and Inefficient Land Use

Fig. 4: Identifying and categorizing the voids within the railway colony.[28]

India's rapid urbanization often leaves behind "urban voids" like vacant plots, abandoned factories, leftover infrastructure spaces, brownfields. Their roots vary: deindustrialization, sprawl, or plain neglect in planning. These reveal inefficiency and missed opportunities. Globally, such gaps signal fragmentation, and India's unchecked sprawl sharpens the problem. The danger isn't just poor land use. One of such example is depicted in the fig 4 where voids are created even after planning . Fragmented spaces deepen divides into internal borders, gated enclaves, fenced-off wealth. This trend raises concerns: when cities fracture, poorer communities lose access to shared resources and a fair urban life.[21]

Social Exclusion and Disconnection from Public Life

Neglected urban spaces fuel disconnection and stagnation, cutting entire areas off from public life.6This creates fragmentation where some neighbourhoods remain polished, while others resemble "war zones" of broken roads and poor sanitation. Affordable housing schemes like PMAY-U expose deeper flaws.[24] Land scarcity that tied to rigid railway control, weak coordination, and unclear rules that delays projects and triggers evictions. Worse, migrants and renters in informal settlements often lack documents, leaving them excluded. Arbitrary cut-off dates and incomplete surveys shrink eligibility further. This trend raises concerns:

policies meant to include the poor often end up institutionalizing their exclusion.

Environmental Degradation and Climate Vulnerabilities

Urbanization in India carries a steep ecological costlike habitat loss, rising emissions, shrinking biodiversity, and worsening heat islands. In practice, weak urban management deepens this decline, eroding resilience. Cities now face flash floods, heat waves, waterlogging, even landslides. Expansion into fragile zones and real estate on floodplains or drained wetlands make matters worse, worsening both flooding and scarcity. The financial toll is high ,over US$300 million spent on flood mitigation in just two years.9 This trend raises concerns: local land-use choices, not just global climate change, are amplifying risk.

Governance Gaps and Implementation Issues in Urban Development

Urban governance in India suffers from deep systemic weaknesses and flaws .Municipal bodies lack autonomy, mismanage funds, and slip into a blame game whenever crises arise. In this vacuum, corruption flourishes like illegal construction spreads, while maintenance budgets quietly vanish. Master Plans rarely align; one agency undoing another's work. Public participation with real voices sidelined. In practice, this creates a cycle of weak accountability and fragmented action. The danger is clear: without institutional reform, even flagship missions risk repeating old mistakes.28

As India faces challenges due to such urban voids these can be overall categorised by fig 5 and it would have a direct impact on government and its governance of the urban space , which can be understood by the table 1 provided below.

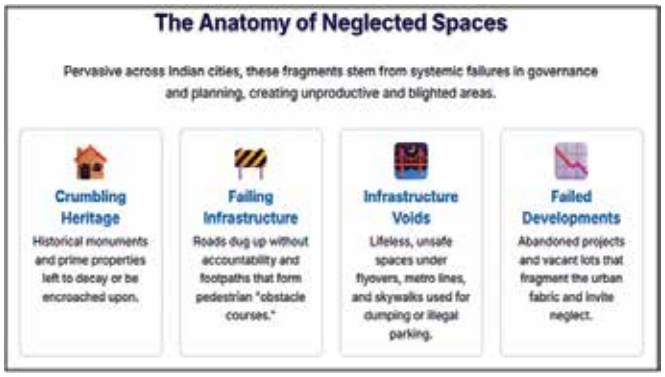

Fig. 5: Identifying and Categorizing the Voids

Table 1: Challenges in Urban Governance and Implementation in India

Challenge Category	Specific Manifestation/Issue
Governance & Accountability	Crumbling monuments, overrun properties, vanishing funds for repairs
	Poor infrastructure maintenance, roads dug up without accountability
	Inefficient municipal services, blame games between departments
	Corruption, illegal construction, vanishing maintenance budgets
Planning & Coordination	Urban Master Plans operating in silos, minimal inter-agency coordination
	Uncoordinated infrastructure projects
	Drainage planning disregarding topography, construction in floodplains/aquifer zones
	"Unmapping" of lakes/tanks, building permissions without environmental assessments
Financial	High cost of borrowing for infrastructure projects
	Inadequate project preparation leading to time/cost overruns
	Reliance on government funding, limited commercial financing
Social & Participatory	Limited public participation, often to expert groups only
	"Pseudo" participation, inadequate representation of vulnerable groups
	Lack of legal documentation for slum households, inadequate surveys, arbitrary cut-off dates for housing schemes
	Stark inequality within cities, uneven distribution of infrastructure benefits
	Bureaucratic barriers, inconsistent plan preparation methodologies, digital divide

SCALABLE STRATEGIES FOR TRANSFORMING URBAN FRAGMENTS INTO COMMUNITY ASSETS

Temporary Interventions: Leveraging Tactical Urbanism

Tactical urbanism uses low-cost, temporary steps to turn neglected streets or corners into lively hubs. Rooted in the "lighter, quicker, cheaper" idea, it lets cities test before spending in bigpedestrian zones, pop-ups, even guerrilla projects. The risks are low, but gains are real: active streets, stronger community ties, people-first spaces. Indian cities are now applying it to vacant plots, messy storefronts, underpasses, these intervention is documented in table 2.The implication is clear: experimentation, not masterplans, often sparks lasting transformation .

Table 2: Illustrative Tactical Urbanism Interventions and their Outcomes in India

Intervention Type	Location (City, Specific Space)	Description of Intervention	Key Outcomes/Benefits	Alignment with Urban Missions/Scalability Potential
Vertical Gardens	Kochi, Metro Pillars	Modular green walls from recycled materials with native vegetation	Absorbs dust, reduces heat, visually softens urban environment, increased civic pride, cooling effect	Aligns with Smart Cities Mission, low-maintenance, low-cost, public-private-volunteer model, easily replicable [7]
Cultural Corridors	Nagpur, Under-viaduct spaces	Murals, sculptures, LED displays, public seating reflecting local heritage, CPTED principles applied	Increased visibility, lighting, pedestrian engagement, reduced loitering, rising footfall, citizen participation in art events	Scalable by replicating cultural programming under other viaducts, adaptable to local heritage, enhances safety [7]
Recreational/Inclusive Zones	Surat, Under-flyover zones	Seating, shaded walkways, open gyms, food stalls, smart lighting, CCTV surveillance, focus on inclusivity	Enhanced usability, safety, 40% increase in nighttime female use, improved lighting perception	Highly scalable for various under-flyover nodes, modular elements, desirable for widespread public use [7]
Bicycle Parking	India (e.g., Gurgaon)	Replaced 4 car parking spots with parking for 40 bicycles (Seeds for Change)	Nurtures social life, outsized social impact with minimal infrastructure, turns parked cars into community assets	Demonstrates "lighter, quicker, cheaper" principle, easily replicable in dense urban areas [33]
Active Street Edges	Ahmedabad, S.G. Road street edges	Study of informal activities and land use at street/building edges to identify active public realms	Supports placemaking, enhances interaction of built form with street movement, adapts to local socio-cultural aspects	Applicable to other Indian cities with similar informal activities and street dynamics [34]

Permanent Interventions: Adaptive Reuse for Sustainable Regeneration

Adaptive reuse gives vacant or aging buildings new life by cutting raw material use, reducing waste, and avoiding costly demolition. It supports a circular economy, proves cheaper than new builds, and revitalizes neighbourhoods without erasing history. Yet challenges persist: balancing preservation with modernization, heritage rules, and tussles among agencies and developers. India, with its layered history, has long practiced informal reuse.Adaptive reuse, especially in heritage structures, is more than physical preservation as it sparks cultural and economic revival at a micro scale. By keeping the “roots of former levels”while layering in new uses, cities preserve their identity and avoid becoming interchangeable. Such example are mentioned in table 3.

Table 3: Adaptive Reuse Examples in India and Contribution to Urban Regeneration.

Category	Project Name & Location	Original Function	New Function	Key Features & Significance
Architectural & Industrial Heritage	**Alembic Industrial Heritage, Vadodara**	113-year-old penicillin factory	Museums, art studios, and exhibition spaces	Retained original riveted trusses and materials, preserving its "raw industrial charm."
Architectural & Commercial Heritage	**Haveli Dharampura, Delhi**	1887 Mughal-style haveli (mansion)	Mixed-use: shops on the ground floor and residences above	Preserved original wooden doors, windows, and marble *jali* work, balancing tradition with utility.
Architectural & Royal Heritage	**Gohar Mahal, Bhopal**	Nawabi palace	Arts and crafts exhibition center and a museum	Supports local artisans and sustains traditional crafts while serving as a cultural hub.
Architectural & Royal Heritage	**Jai Vilas Palace, Gwalior**	19th-century European palace	Partially converted into the Jivajirao Scindia Museum, with the royal family still residing in another part.	A "living example of heritage continuity" where history and modern life coexist.
Architectural Heritage	**Kandadu, Pondicherry**	A historical building	Restored building (specific new use not detailed, but implied to be residential/commercial)	Restoration focused on celebrating historical imperfections by leaving damp patches and peeling plaster exposed, and using local craftsmen.
Architectural Heritage	**Calcutta Bungalow**	90-year-old home	Heritage bed-and-breakfast	Evokes the "Golden Era" of the city's architecture and promotes heritage tourism.
Industrial/Commercial Voids	**Soro Village Pub, Goa**	1940s industrial warehouse	Bar/social hub	Retained a "raw 'hip warehouse' aesthetic," demonstrating how simple design can preserve industrial character.
Infrastructure Voids	**Under Metro Lines & Flyovers**	Neglected, empty spaces beneath public infrastructure	Vertical gardens, cultural corridors, and recreational zones	Transforms previously "uninviting urban fragments" into social assets, solving a "design problem" of urban neglect.

Compact Mixed-Use Development: Fostering Integrated Urban Living

Compact mixed-use developments are quietly reshaping Indian cities like homes, offices, leisure stitched into dense fabrics. The benefits are immediate: fewer car trips, shorter commutes, lighter traffic, even less stress. Shared cafés, gyms, and courtyards replace anonymity with identity. For investors, steady demand ensures resilience. Yet the deeper shift is cultural with proximity and community begin to rival skyline and scale. Environmentally, green roofs, solar panels, and rain harvesting cut footprints while aligning with LEED or GRIHA. In practice, they double as lifeboats in crises, offering shelter and resources. The implication is clear: mixed-use, rooted in local culture, advances affordable, resilient, 15-minute cities. These changes have different impact and relevance to Indian context and shown in table provided.

Table 4: Key Benefits of Compact Mixed-Use Developments for Indian Cities

Category of Benefit	Specific Benefit	How it's Achieved	Relevance to Indian Context
Economic	Higher Investment Value/Returns	Diversified revenue streams (residential, commercial, retail), steady demand	Attracts investors, boosts local economies in rapidly urbanizing cities [39]
	Local Economic Growth & Employment	Built-in demand for local businesses, increased foot traffic, job creation in various sectors	Supports local entrepreneurs, addresses urban unemployment challenges [39]
Environmental	Reduced Carbon Emissions & Urban Sprawl	Less need for extensive travel, cutting down on vehicle emissions; efficient land use	Critical for India's climate goals and managing rapid urban expansion [40]
	Sustainable Practices	Incorporation of green roofs, solar panels, rainwater harvesting, energy-efficient designs	Promotes eco-friendly urban development and resource conservation [40]
	Efficient Infrastructure & Resource Use	Sharing systems for water, power, waste management across residential/commercial spaces	Optimizes resources, aligns with sustainable urbanization goals, green certifications (LEED, GRIHA) [39]
Social	Improved Walkability & Reduced Commute	Combining homes with offices, retail, and amenities; promotes walking over driving	Enhances quality of life, reduces traffic congestion and stress in dense cities [39]
	Stronger Sense of Community	Shared spaces (cafés, parks, fitness centers) encourage social connections and interaction	Fosters vibrant community spirit, addresses social isolation in diverse urban settings [39]
	Work-Life Harmony	Integration of co-working spaces, gyms, recreational areas alongside homes	Supports flexible remote work cultures, reduces commute burden for professionals [40]
Urban Planning	Optimal Land Use & Urban Infill	Efficient use of limited urban land, especially for affordable housing (TOD)	Crucial for addressing land scarcity and housing crisis in Indian cities [39]
	Community Resilience	Self-contained infrastructure and multi-purpose facilities	Enhances ability to withstand and recover from disasters, provides shelter and resources [40]

ENABLING FACTORS FOR SUCCESSFUL URBAN TRANSFORMATION

Community involvement is key to India's sustainable urban growth. When citizens shape decisions, projects gain trust, ownership, and shared responsibility. Yet, too often participation is tokenistic. Slum households miss outpapers, deadlines, digital gaps block them. The result? Initiatives that seem inclusive but rarely are. Programs like PRIA in Chhattisgarh or INCLUDe show real promise, linking resident input to budgets and reducing dependency. Still, weak laws and planners undervaluing local knowledge make gains fragile. Think tanks like NIUA help scale context-driven solutions as in fig 6 we see how open spaces are created according to the scale of observation , which further helps in giving better solutions of improvement .Many such example cacn be seen in india as shown in table 5. But India's push for "smart" citiesrisks sidelining community voices. This trend raises concerns for equity and relevance.India's turn to contextual design breaks from Western models. It favors indigenous, climate-tuned solutions that feel socially legible. However, ignoring such nuance risks cities that look efficient on paper yet remain detached from their people.

Table 5 : Illustrative examples from India highlight this philosophy

Project Name	Architect/Designer	Key Design Principle	Impact/Outcome
Aranya Low-Cost Housing (Indore)	Doshi sir	Responds to lived realities and user needs, allowing for home expansion and adaptation.	Fosters a sense of ownership and community growth by prioritizing flexibility over rigid uniformity.
Belapur Housing	Charles Correa	Creates a hierarchy of open spaces (cascading courtyards) from private to semi-shared areas.	Transforms housing into a living neighborhood by encouraging interaction and social connection among neighbors.
Hathigaon (Jaipur)	Rahul Mehrotra	Employs climate-responsive design to create a microclimate that cools the houses and courtyards.	Enhances comfort and reduces the need for mechanical cooling by aligning architecture with its environment.
Sanjay Nagar Slum Redevelopment Project	N/A	Emphasizes resident participation, allowing locals to co-design layouts and manage parts of the process.	Builds homes and trust simultaneously, demonstrating that urban rehabilitation is most successful when residents are active partners.

Fig. 6: Hierarchical Open Spaces[35]

Financial Viability and Public-Private Partnerships (PPPs)

India's urban transformation comes at a steep price. The nation needs $4.5 trillion in infrastructure by 2030, yet projections hint at a $526 billion shortfall by 2040. Meeting rapid urbanization would demand $55 billion annuallyabout 1.2% of GDPwhile historic spending barely reached 0.6%. This trend raises concerns: government funds still cover 72% of costs, private financing just 5%. Bridging the gap calls for creativity.

Cities are experimenting with land value capture, InvITs, and user fees. Well-designed projects can attract pension funds and global investors, suggesting India's urban future may hinge as much on financial innovation as on urban design. Cost-effective smart city strategies like LED streetlights, BRTS corridors, smart waste, low-cost housingshow that scalable, practical solutions matter more than flashy tech. But scattered pilots risk fragmentation. PPPs offer expertise and faster execution, yet without stronger Urban Local Bodies to make projects bankable, private money may never truly flow

Policy Alignment and Recommendations for Viksit Bharat 2047

Smart Cities Mission: Achievements, Limitations, and Future Directions for Neglected Spaces

Launched in 2015, the Smart Cities Mission promised to fix chronic urban headaches of traffic, flooding, pollutionby blending tech with design. Its core, Area-Based Development, created showpiece zones. Some wins were visible: digital libraries in 41 cities, 59,000+ CCTVs improving safety. Critics note smart enclaves emerged while the poor stayed excluded. In practice, funds lapsed, basics lagged. The implication is stark: India now needs a people-first, Sustainable Cities Mission.[30]

AMRUT 2.0: Enhancing Basic Services and Green Spaces in Urban Regeneration

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) 2.0 launched as a successor to its first phase, pushes urban regeneration through basics that are anything but smalluniversal tap water, sewerage in 500 cities, greener spaces, cleaner air. The mission's heavy focus on water conservation, harvesting, recycling, restoring lakes that signals a shift toward ecological growth. Weak ULBs, and low public participation remain bottlenecks. The larger point is clear: unlike Smart Cities' tech enclaves, AMRUT 2.0's people-first lens could drive inclusive regenerationif execution holds..[52]

Integrating Climate Resilience into Urban Planning and Infrastructure Development

India faces a rare window to shape its urban future with climate-conscious strategies. Nearly 70% of 2047 infrastructure is yet to be builtan enormous risk, but also opportunity. Cities drive 70% of emissions while sprawl worsens heat and floods. Resilience now means anticipatory planning: blue-green infrastructure, stricter energy codes, real-time risk mapping. However, politics often undercuts progress of lakes erased, flood zones built over, land commodified. The implication is clear: unless governance treats ecosystems as foundation, green fixes risk staying cosmetic, not transformative.

Policy Recommendations for a Regenerative, Equitable, and Resilient Urban Model

Reclaiming neglected urban fragments will require a multi-layered policy push ,combining planning, finance, ecology, and social equity. Integrated approach can be adopted as in to cater the problems as shown below in the table 6 .

Table 6 : Recommendation of different change that can be applied

Shift from Symptomatic to Systemic Solutions	Urban policy must address root causes and structural inequalities, not just isolated problems, to be effective.
Prioritize People-Centric Planning	Urban development should prioritize the needs of people, especially the most vulnerable, over profit or technology.
Strengthen Urban Governance and Accountability	There is a need for independent audits and strict civic enforcement to counter fund mismanagement and institutional inertia.
Mandate Inclusive and Participatory Planning	Public voices should be integrated into urban planning from the beginning, moving beyond mere "checkbox" consultations.
Integrate Ecological Function into Land Use	Urban planning must respect natural systems like floodplains and recharge zones to prevent future crises.
Promote Sustainable and Regenerative Infrastructure	Building codes and incentives should encourage green and circular economy practices to reduce waste and promote sustainability.
Foster Innovative Financing and PPPs	Urban Local Bodies need to develop new financing methods, like municipal bonds, to attract private investment and fund sustainable projects.
Address Affordable Housing Systemic Issues	Stronger state policies are needed to coordinate land release and simplify eligibility processes to provide affordable housing for low-income families.

CONCLUSION:

Neglected urban fragments reveal India's layered crisesweak governance, unplanned growth, and deep divides. Yet they aren't just liabilities; with foresight, they can drive regeneration. Temporary tactics like tactical urbanism test ideas cheaply, while adaptive reuse and mixed-use hubs restore identity and counter sprawl. But transformation hinges on enablers: genuine participation, context-sensitive design, and financing beyond token PPPs. Smart Cities and AMRUT provide foundations, yet without inclusive, ecologically grounded governance, progress is patchy.

The implications are clear: Viksit Bharat 2047 demands turning urban scars into community assetsor risk leaving inequalities entrenched. Institutional reform must enforce accountability; policy innovation must embed equity and resilience; citizen empowerment ensures plans are lived, not just paper. Strong ULBs can attract private capital, and context-specific solutions avoid generic failures. In practice, even a repurposed street corner or heritage building can ripple into social cohesion, economic vitality, and environmental reliefbut only if execution is consistent, long-term, and people-centered.

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STREAMLINING CONSTRUCTION PERMITS IN DELHI: SINGLE-WINDOW REFORMS TRANSFORMING 'DOING BUSINESS'

Vishv Ratan Bansal* And Dr. Aqil Ahmed**

Abstract

This paper critically examines the reforms implemented in Delhi's construction permit system under the Government of India's Ease of Doing Business (EoDB) initiative, with a particular focus on the Online Building Permission System (OBPS), a single-window clearance mechanism and associated reforms, including Unified Building Byelaws (UBBL 2016). Through process mapping and institutional analysis, it analyses the key innovations, including the adoption of risk-based classification of buildings, integration of multiple external agencies onto a unified digital platform, introduction of deemed approvals, and greater reliance on automated scrutiny and joint inspections. These reforms have improved efficiency, accountability, and transparency, while contributing substantially to India's rise in the World Bank's Doing Business rankings. At the same time, persistent challenges—such as digital illiteracy amongst small developers, interdepartmental coordination hurdles, weak enforcement in informal settlements, and uneven adoption across geographies—underline the limits of regulatory simplification in a complex urban context. The study concludes that while Delhi's experience offers a scalable and replicable model of urban governance innovation, continued stakeholder engagement, system integration, inclusive implementation, and feedback-driven policy refinement will be essential to sustain and improve this transformation in the coming years.

INTRODUCTION

The construction permit system in Delhi has undergone significant reform as part of India's broader "Ease of Doing Business" (EoDB) initiative led by local authorities. Traditionally characterised by complexity, multiple agency approvals, lengthy timelines, and redundant inspections, the previous system posed major challenges for developers, architects, and entrepreneurs. Recognising the need to simplify procedures, reduce approval times, and foster investor confidence, the Municipal Corporation of Delhi (MCD) introduced a comprehensive set of reforms centred around a digital single-window clearance system called the Online Building Permission System (OBPS).

Before proceeding, it is essential to understand some key terms.

Ease of Doing Business

The World Bank's 'Doing Business Report (DBR) refers tothe Ease of Doing Business (EoDB) index as a ranking system established by it that assesses and ranks countries based on the regulatory environment for starting and operating businesses. As regards the construction permit, Doing Business records all procedures required for a business to build a warehouse, along with the time and cost to complete each procedure. In addition, Doing Business measures the building quality control index, evaluating the quality of building regulations, the strength of quality control and safety mechanisms, liability and insurance regimes, and professional certification requirements.

In 2014, the Government of India launched the Business Reforms Action Plan (BRAP), an ambitious program of regulatory reforms aimed at creating a more business-friendly environment in the country. These reforms prioritised simplification of licensing and permitting processes, rationalisation of inspections, digitisation of services, risk-based regulation, operationalisation of a single-window clearance system, and greater transparency in the entire process. As a result, India's global ranking in the World Bank's Ease of Doing Business Index improved from 142ndout of 190 countries in 2014 to 63rdin 2020,besides being recognised among the world's top ten improvers for the third consecutive year, reflecting the government's commitment to fostering competitiveness, efficiency, and investor confidence in the regulatory ecosystem.

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PERFORMACE COMPARISON IN DBR 2019 and 2020

Factors	DBR 2019	DBR 2020	DBR 2021
Procedure (No.)	16	11	7
Time (Days)	91	113.5	59
Cost (%)	4.2	2.80	1.31
Quality (out of 15 Points)	14	15	15
Rank of India in Construction Permits	52	27	—
Rank of Delhi in Construction Permits	28	13	7 (Projected)

Construction Permit

A construction permit, or building permit, is a statutory authorisation granted by the local authority to initiate construction, alteration, or redevelopment of a structure. More than a procedural requirement, it serves as a vital regulatory safeguard, ensuring compliance with local building norms, safety standards, and zoning regulations, thereby protecting both public safety and urban order.

Reforms in construction permits have been a core area under the Ease of Doing Business (EoDB) initiative and were a key driver behind India's sharp improvement in global rankings—from 184th place in 2014 to 27th in 2020. Among Indian cities, Delhi emerged as a frontrunner, achieving a score of 84.2/100 in 2020, thereby outperforming Mumbai and even China and thereby establishing itself as a benchmark for regulatory modernisation and urban governance efficiency in this sector.

REFORMS IN CONSTRUCTION PERMITS IN DELHI

Since 2016-17, Municipal Corporation of Delhi has been implementing the Online Building Plan Sanction (OBPS) system, and all Building Plan approvals, including the grant of water/sewage connections, were gradually shifted to the RMS-enabled OBPS portal of Municipal Corporation of Delhi (MCD), making a shift from predominantly offline mode to fully digital mode. In 2022, the system was shifted from RMS-enabled software to the new NexGen OPBS system supported by AWS cloud support, with a new and modified rule engine with faster processing speed and a host of other features compatible with modern-day requirements.

Ease of Doing Business, between the period 2016 to 2020, showed a sharp reduction in

i. Procedures: Reduced from ~29 steps in 2016 to 11 steps by 2020 and further reduced to 7 procedures.

ii. Time: Approval time dropped from 213 days in 2016 to about 113.5 days in 2019-20, further reduced to 59 days

iii. As %age of warehouse value, Delhi's cost in getting the construction permit improved to 2.8%, compared to South Asia's average of 12.5% and Mumbai's 5.4%.

PR. No.	Procedures (as per UBBL-2016)	Time (As per UBBL-2016)
Procedure-1	Submit online Common Form along with the requisite building permit fee and drawings	30 Days
Procedure-2	Request and obtain the release of building sanction plans	
Procedure-3	Submit online notice of completion up to the plinth level.	7 Days
Procedure-4	Request and receive Inspection at the plinth level and obtain online approval of the plinth completion	
Procedure-5	Submit notice of Completion along with the Fire NOC application form, water and sewer connection, and request final inspection	22 Days
Procedure-6	Receive final inspection of the construction from MCD, Fire Department and DJB (wherever applicable)	
Procedure-7	Obtain a completion/ occupancy permit online	
	Total Procedures- 07	Total Time- 59 Days

(Procedure table mentioning 7 procedures)

Standardised By-Laws and Risk-Based approach

i. In 2016, the Delhi Government approved 'Simplified and User-friendly Building Byelaws, updating outdated provisions to support safer, green, and transparent approvals.

ii. Introductions included

- Risk-based Building categorisation with faster clearances for projects of lower risk categories
- Mandatory latent defect liability period for Builders and professional liability insurance for the professionals, i/c, Architects, Engineers, Structural Engineers, and others associated with the project.
- Stipulated professional criteria for Architect/ Engineer
- Environmental Clearance, which was required for buildings having a covered area of 20,000sqm and more, has been relaxed, and now the MCD has been empowered to issue Environmental Clearance up to 1,50,000 sqm. However, as of now, it has been stayed by the Hon'ble High Court, and the matter is still under adjudication.

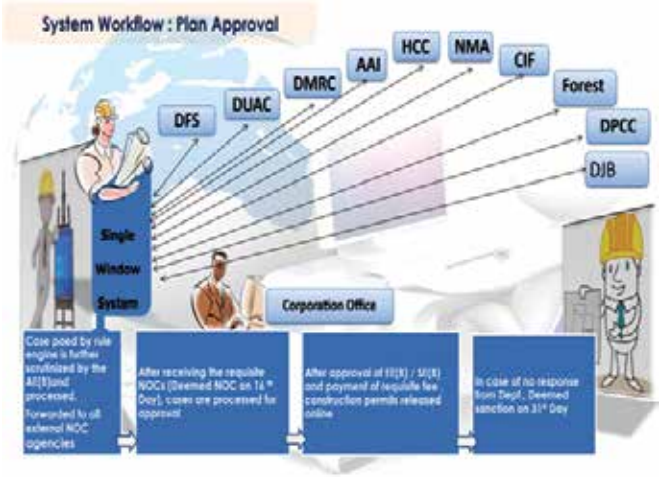
Online Building Plan Sanction

Online Building Plan Sanction System is a digital platform used by the Government Authorities or Local Bodies to streamline the process of approving Building plans and issuing Construction permits. It allows architects, engineers, builders, and property owners to submit their building plans electronically.

SALIENT FEATURES OF MCD OBPS

1. Online submission and approval of building plans.
2. Assigning Unique Identification numbers to every application, which can be used

   for all transactions, tracking, and follow-up.
3. The system generates a discrepancy report, if any, on failing the self-approval test.
4. Issuing Building Plan Approvals, Plinth level inspection Reports and Occupancy-cum-Completion Certificate after completion of work according to the plan.
5. All external agencies, e.g., DFS, NMA, DMRC, CIF, DUAC, HCC, BSES-BYPL, BSES-BRPL, TPDDL, DJB-water, DJB Sewerage, AAI, Forest Department, and DPCC, and internal agencies, e.g., Town Planning and Law Department, are integrated in the OBPS.
6. Two-Step Payment for all applicable charges, including Labour Cess. Plan Fee is to be paid at the time of request submission, and Sanction Charges are to be paid before plan release. All payments, including payment of NOC fee and Charges, if any, for all service Departments have also been integrated at one place through a common payment gateway. Payment is accepted through e-Payment only, and Cash payment has been dispensed with.



THIS IS SUPPORTED BY THE FOLLOWING MAJOR FEATURES

Common Application Form

To streamline the sanction of Building plans, Common Application Form (CAF) under Single Window Clearance System (SWCS) has been devised and is in operation, under which building plan cases are submitted for approval of the Local Body in Delhi and simultaneously referred for NoC to the concerned Departments already integrated through the system such as Delhi Fire Service (DFS), Archeological Survey of India (ASI), Delhi Metro Rail Corporation (DMRC), Delhi Urban Art Commission (DUAC), Forest and Heritage Conservation Committee (HCC) etc. for sanction of building plan of residential, commercial, warehousing, Institutional and Industrial buildings in all areas of Delhi. The internal agencies, e.g., Town Planning Department or Law Department, from whom comments may be required during the approval process, are also integrated in OBPS.

(Image of Common Application Form)

- **Process of Building Plan approval:** -Under this system, the applicant submits his building plans along with the requisite documents as applicable and the processing fee for approval. The Rule-engine makes the initial scrutiny of the building plan application on the basis of the data provided by the applicant. Intimation is sent to the applicant in case of any discrepancy.

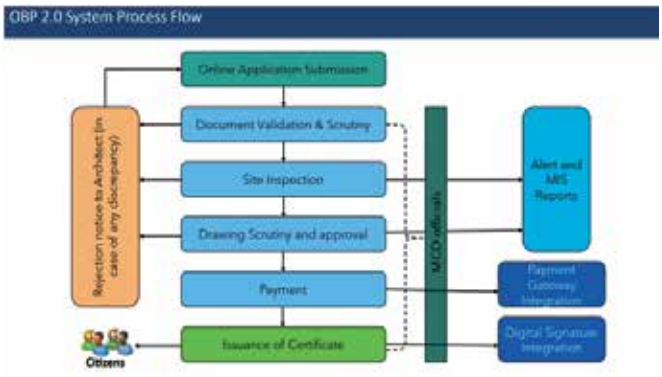
  Once the application passes through the initial scrutiny by the rule engine, the building plans are digitally forwarded to the concerned Assistant Engineer of the Building Headquarters, for further scrutiny and approval, besides simultaneously forwarding it to the external/ internal NOC agencies selected, if any, for the grant of requisite NOC. The building plans are further scrutinized by the concerned Assistant Engineer with regard to applicable byelaws and other rules and regulations in force, and in case any discrepancy is noticed, the building plans are referred back to the applicant owner/ architect for rectification, who carries out the necessary rectification and resubmits the plans for approval. In case the building plans, along with the necessary documents submitted, are found to be in order as per byelaws and other rules and regulations in force, the building plans are processed for approval as per the delegated powers. Approval notice is sent to the applicant for payment of requisite charges, and after the payment is made, digitally signed building plans are released for downloading by the applicant. In case of Non-compliance or partial compliance of the notice conveying the discrepancies, the building plan application is rejected, and the rejection note is conveyed to the applicant. The total procedure from the time application is made and the approval or rejection is conveyed must be completed within 15 days for very low and low risk category cases whereas after which the application is deemed approved. Similarly, in refer-back cases, if the applicant fails to resubmit the application, after necessary compliance of the discrepancies conveyed, within 15 days of its refer-back, the application is deemed rejected by the system. These timelines in other risk-category cases are 30 days.

  In cases where NOC from one or more agencies is required, the application is simultaneously forwarded to all the agencies concerned, and the agencies must decide on the building plan application within 15 days. In case the NOCs are not decided by the respective NOC agencies within the stipulated time period, the NOC is deemed to have been granted, and the system forwards the case to MCD for further processing. This system runs as a parallel activity to the processing of building plan applications in the MCD.

  A similar procedure is adopted for applying for plinth-level inspections as well as the Occupancy cum Completion Certificate.

- **Joint site inspections**

  In cases of Moderate or high-risk buildings, now, only a single joint-site inspection is held by all the NoC agencies on a date generated by the system. Generally, the system fixes Joint site inspections for Tuesdays or Thursdays. The joint report is signed by all the participating NoC agencies and uploaded on the system on the same day.



Color Coded Zonal Maps

To ascertain the requirements of NoC from external agencies for a particular property, Colour Coded Zonal Maps (CCZM) have been prepared for the external NoC agencies, namely DUAC, DMRC, ASI, and AAI, the links of which are also provided on the MCD website.

To further streamline the CCZMs, a single superimposed CCZM map has been prepared through Geo Spatial Delhi Limited (GSDL), making it easier to determine the requirement of NoC. The link to Geo Spatial Delhi Limited (GSDL) –Government of NCT of Delhi has also been uploaded on the website of MCD.

Deemed Sanction and Deemed NOC

Earlier, the Building Plan sanction used to take 3-4 months, and in cases where NoC from more than one Department was required, the time taken was even longer, but now under the EODB, the building plans are being sanctioned within a maximum of 30 days. In case the plans remain pending on the part of the department, a deemed sanction is being imposed by the system.

Similarly, if NOCs are not granted in 15 days, the same is treated as the deemed NoC of the external agency, and the building plan is sanctioned without delay through the online system. These deemed sanctions/rejections are backed by the provisions of the DMC Act and Delhi UBBL-2016.

Average Time of Sanction

The average time of sanction from 08/04/2016 to date has been reduced to about 19 days, which is the major reform done by the Municipal Corporation of Delhi. In this period, all the applications filed have been decided within the stipulated period. About 160 building plans have been sanctioned on the same day, and the majority of residential plans for which no NOC is required have been approved within 7 days.

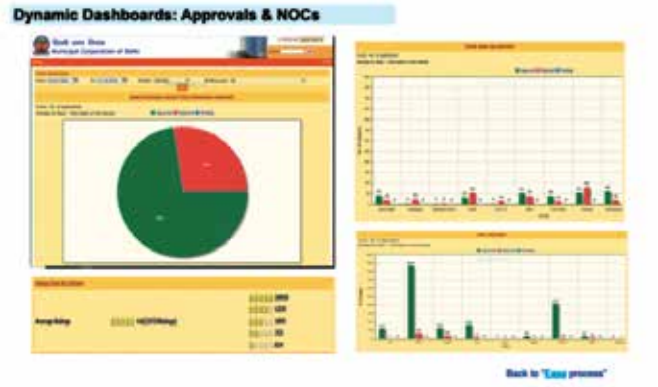
OTHER REFORMS UNDER THE SINGLE WINDOW CLEARANCE SYSTEM

- No. of affidavits/undertakings required to be submitted along with the Building plan application have been replaced by a single e-undertaking
- Requirement of No Tax Dues certificate has been done away with.
- The process of the Intimation of Start of Construction has been dispensed with in UBBL-2016.
- The number of documents required for sanctioning the building plan has been reduced from 39 to 7
- Building permits issued online with digital signature. No personal visit is required
- Road Cutting and restoration charges for water and sewer connections are collected only for a length up to 5 mts, thereby reducing the cost of obtaining a Construction Permit
- Digitally signed Occupancy–cum-Completion (OCC) Certificate issued online
- Provision to submit site photographs introduced, thereby eliminating the requirement of on-site inspection for Low-Risk Buildings.
- SARAL Scheme introduced for building plans of residential properties up to a plot size of 105 sq mts. Under which self-certification of the owner is sufficient, Intimation of which by the Architect is acknowledged without any physical visit. For the plinth level inspections and issuance of Occupancy cum Completion Certificate, again, self-certification of the owner is sufficient with due intimation by the Architect on the OBPS portal.
- For residential properties of plot size up to 500 sqm., the SPECIAL SARAL Scheme is introduced where sanction of building plan is accorded by the Architect through the online portal of MCD without any interference by the department. In cases where NoC is required from any of the external departments, an undertaking from the Architect along with the relevant site photographs is sufficient. As for the plinth level inspections and issuance of Occupancy cum Completion Certificate, the procedure is the same as for the building plan sanction in such cases.

STEPS TAKEN FOR INCREASING THE TRANSPARENCY / BENEFITS TO THE APPLICANTS

- The applicant need not visit the office of any NoC agency as the CAF has been integrated with all the external departments

- Increased Transparency as the status of the plan can be sanctioned online at any point of time.
- There is no physical interaction between the department and the applicant, thereby eliminating the chances of corruption
- SMS and e-mail to the applicant at all stages of the sanction, right from application submission to plan release
- The submission of hard copy has been dispensed with since 08/04/2016
- The payment of the fee is online only, by net banking, Debit card / Credit Card, RTGS/NEFT, etc.
- Digitally signed sanction letters are being issued, which can be downloaded online by the architect / Owner
- Dynamic Dashboard showing all cases received are projected online on real time basis, which are placed in the public domain
- A dynamic dashboard for NOC from external agencies is also placed in the public domain.
- All FAQs, Circulars, and checklists are available on the website.



(Pic of dynamic dashboard)

FEEDBACK FORA

- WhatsApp groups for architects and professionals to address their day-to-day queries.
- Stakeholders' meetings are held frequently to get feedback on further improvements
- Stakeholders' workshops are held at regular intervals for the dissemination of improvements and exchange of views.
- Facebook page "MCD Ease of Doing Business" for public interaction.
- Every change in application status is notified to the applicant and architect by SMS and email.
- Star rating of online system by users introduced; 5-star rating has been given in more than 85% of cases.

IMPACT ON PROCESS AND TIME

Efficiency gains

- Procedure count dropped by more than 75% (from 29 → 11 → 7 procedures)
- Approval time has shrunken from 213 days → 113 days and further to 31 days.
- Cost for obtaining a construction permit as a percentage of total construction cost has dropped to ~ 6.6% for Mumbai and ~ 4.2% for Delhi, and for standard warehouse projects to ~2.8% of the project cost.
- Switching to digital OBPS has provided working-time flexibility to the stakeholders, improving their efficiencies.

Improvement in Quality Control

- In DBR-2020, Delhi scored 15/15 on the Building Quality Control Index- the highest possible score; comparable to the best-performing economies such as Hong Kong.

Transparency and accountability

- Integration with DPCC dust portal is transparency-driven, enabling real-time enforcement and automatic penalties.
- The switch to digital OBPS portal has cut face-to-face interaction between the department and the architect/owner, eliminating corruption (architect fee, unofficial delays)

CHALLENGES AND AREAS FOR FURTHER IMPROVEMENT

Uneven adoption of Building Approvals

- Despite the online system, a smaller population of Delhi's construction follows legal permit routes; the rest remain unauthorized/unaligned

with sanctioned Building Plans. For example, more than 1700 unauthorized colonies officially exist in Delhi where Building Plans are not sanctioned because of their illegal status and non-application of the building by-laws in these areas.

Geographical Inequity

- Old Delhi areas e.g. Walled City and Rural Colonies struggle with outdated infrastructure such as narrow lanes, their distinct character making compliance with modern by-laws impractical.

Implementation Hurdles

- Issuance remains uneven; high unauthorized construction persists
- Enforcement challenges (fraudulent delays, staffing shortages etc)
- Inclusion of older and informal colony regions
- Sustained willpower and maintaining digital infrastructure over the long term

WAY FORWARD

- Strengthen on-ground enforcement to boost permit adoption
- Allocate more staff, training, and accountability for MCD approvals
- Extend digital systems to rural/unplanned colonies while relaxing unrealistic norms
- Monitor policy impacts via data dashboards, public feedback, and periodic reforms

CONCLUSION

In conclusion, Delhi's construction-permit reform demonstrates a scalable and replicable model for urban governance innovation, having significantly streamlined the Construction Permit system despite the challenges faced. The system has already been adopted by many cities, e.g. Raipur, Kolkata, Bangaluru, etc., with suitable modifications to suit local conditions. The shift to a single-window, risk-based, and citizen-centric approval mechanism has made the permitting process more efficient, accountable, and investor-friendly. However, continued stakeholder engagement, system integration, and feedback-driven policy refinement in the future are also essential to sustain and further improve this transformation in the coming years.

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R&D FOR FRONTIER TECHNOLOGIES FOR THE FUTURE: PAVING THE WAY FOR VIKSIT BHARAT 2047 IN INFRASTRUCTURE DEVELOPMENT

Rajesh Kumar Das*

Abstract

India's vision of Viksit Bharat by 2047 envisages a Developed Nation with robust, sustainable infrastructure that supports economic growth, environmental resilience and societal well-being. At the heart of this transformation lies Research and Development (R&D) in Frontier Technologies, which are poised to revolutionize infrastructure sectors such as construction, urban planning, transportation and energy systems.

This article explores the critical role of R&D in advancing technologies like Artificial Intelligence (AI), Internet of Things (IoT), Block chain, 3D Printing and Green Innovations for infrastructure. Drawing from recent policy frameworks, including the Anusandhan National Research Foundation (ANRF) and NITI Aayog's initiatives, it examines India's current R&D landscape, key challenges such as low investment and digital divides and strategic opportunities through public-private partnerships. By fostering innovation in smart cities, multimodal transport and sustainable buildings, R&D can address urban challenges and drive inclusive development. The discussion underscores how targeted investments and collaborations will enable India to achieve self-reliance in infrastructure, aligning with global standards while meeting local needs. Ultimately, this positions R&D as the cornerstone for a resilient, technology-driven built environment by 2047.

INTRODUCTION

The aspiration for Viksit Bharat 2047, marking India's centenary of independence, is a comprehensive blueprint for transforming the Nation into a developed economy with a GDP exceeding $30 trillion, characterized by equitable growth and sustainability. Infrastructure development is pivotal to this vision, serving as the backbone for economic activities, urbanization and quality of life improvements. As highlighted in NITI Aayog's approach paper, infrastructure must evolve through innovation to support sectors like manufacturing, services and agriculture. However, traditional approaches are insufficient amid rapid urbanization, climate change and resource constraints. Frontier technologies—emerging tools at the cutting edge of science and engineering—offer solutions by enhancing efficiency, reducing costs and promoting sustainability.

R&D in these technologies is essential for customizing global innovations to India's context, such as integrating AI for predictive maintenance in bridges or IoT for smart water management in buildings. This article delves into how R&D can propel frontier technologies for future infrastructure, drawing on recent advancements and policy drives to outline a roadmap for Viksit Bharat.

*Additional Secretary to the Govt. of Tripura

FRONTIER TECHNOLOGIES IN INFRASTRUCTURE: AN OVERVIEW

Frontier technologies encompass AI, machine learning, block chain, robotics, biotechnology, nanotechnology and advanced materials, all with profound implications for infrastructure. In construction, 3D printing enables rapid, cost-effective building of affordable housing, reducing material waste by up to 60% and construction time by 70%. For instance, AI-driven predictive analytics can optimize urban planning by forecasting traffic patterns and energy demands in smart cities.

IoT integrates sensors into infrastructure for real-time monitoring, such as in bridges and dams, enhancing safety and longevity. Block chain ensures transparent supply chains for construction materials, combating corruption and ensuring quality. Green technologies, including bio-based materials and carbon-capture systems, align with India's net-zero goals by 2070, supporting sustainable infrastructure. Multimodal transport systems, as envisioned in Viksit Gujarat 2047, leverage AI for seamless integration of roads, rails and waterways, reducing logistics costs.

These technologies are not mere enhancements; they are transformative. In the context of Viksit Bharat, they address urban challenges like congestion and pollution, fostering resilient infrastructure that withstands climate impacts.

INDIA'S R&D LANDSCAPE: POLICIES AND INITIATIVES

India's R&D ecosystem is evolving rapidly, driven by Government Policies aimed at boosting innovation. The ANRF, established to catalyze private R&D, targets increasing India's R&D expenditure from 0.7% of GDP to 2% by 2047, fostering collaborations between academia, industry and startups. This aligns with the National Education Policy 2020 and the Science, Technology and Innovation Policy 2021, which emphasize frontier tech for self-reliance.

NITI Aayog's Frontier Tech Hub, launched in 2025, focuses on AI, quantum computing and biotech for societal development, including infrastructure applications like digital twins for urban simulations. The Pradhan Mantri Gati Shakti National Master Plan integrates technology for coordinated infrastructure planning, using GIS and AI for efficient project execution.

Public-private partnerships are key, with initiatives like the Atal Innovation Mission expanding to 50,000 tinkering labs, nurturing young talent in robotics and IoT. Defence and aviation sectors, as noted by the Raksha Mantri, leverage world-class infrastructure for frontier tech R&D, spilling over to civilian applications like high-speed rail. KPMG's roadmap highlights digital infrastructure, including 5G and edge computing, as enablers for smart buildings and IoT ecosystems.

These efforts position India as a Global R&D hub, with investments in eight key arenas like semiconductors and renewable energy, as per McKinsey.

CHALLENGES IN SCALING R&D FOR FRONTIER TECHNOLOGIES

Despite progress, challenges persist. India's R&D investment remains low compared to global peers (e.g., 2.8% in the US), limiting breakthroughs in frontier tech. The digital divide exacerbates inequalities, with rural areas lacking access to high-speed internet essential for IoT deployment in infrastructure. Cyber security threats pose risks to smart infrastructure, as interconnected systems become vulnerable to attacks.

Skill gaps in emerging fields like quantum computing hinder adoption, while bureaucratic hurdles slow technology transfer from labs to projects. Environmental sustainability adds complexity, as frontier tech must balance innovation with low-carbon footprints. In infrastructure, high upfront costs for technologies like 3D printing discourage small builders, necessitating subsidies and pilots.

Addressing these requires a holistic approach, as outlined in the Road to Viksit Bharat, emphasizing digital infrastructure and skill development.

OPPORTUNITIES AND STRATEGIC RECOMMENDATIONS

Opportunities flourish in leveraging India's demographic dividend and startup ecosystem. With over 1,00,000startups, India can drive R&D in affordable frontier tech for infrastructure, such as drone-based surveying for remote areas. Policy interventions, like tax incentives for R&D, can attract foreign investment, fostering global partnerships.

Strategic recommendations include tripling R&D funding through ANRF, establishing dedicated centers for infrastructure tech and integrating AI in public works departments. Public-private models, as in Viksit Bharat blueprints, can accelerate adoption, with examples like Bengaluru's Smart City projects using IoT for traffic management. Emphasizing Green R&D, such as nanotechnology for durable roads, aligns with sustainability goals.

International collaborations, highlighted at the Hoover Institution event, can bring best practices, while empowering entrepreneurs through eased regulations will invigorate innovation.

CASE STUDIES: FRONTIER TECH IN ACTION

India's metro systems exemplify frontier tech: Delhi Metro uses AI for predictive maintenance, reducing downtime by 30%. In housing, the PMAY scheme incorporates 3D-printed homes in Gujarat, showcasing cost-effective sustainable construction. Block chain pilots in land records by states like Maharashtra enhance transparency in infrastructure projects.

These cases demonstrate scalable impacts, paving the way for Nationwide rollout by 2047.

CONCLUSION

R&D in frontier technologies is indispensable for realizing Viksit Bharat 2047's infrastructure ambitions. By overcoming challenges through strategic investments and collaborations, India can build a future-proof built environment—smart, sustainable and inclusive. With concerted efforts, India will emerge as a Global Leader in innovative infrastructure, fulfilling the vision of a Developed Nation.

BUILDING A SUSTAINABLE FUTURE: AN INTEGRATED APPROACH USING DIGITAL SYSTEMS, BIO-BASED MATERIALS AND GREEN HYDROGEN

Akshay Sanyal*

Abstract

In a world where resource depletion and the climate problem are getting worse, innovative technologies are essential for achieving sustainable development. This paper critically reviews several frontier technologies—including AI, blockchain, bio-based materials, and green hydrogen—as crucial tools for advancing the United Nations Sustainable Development Goals (SDGs). By synthesising insights from academic literature, policy reports, and case studies, we identify three key areas of transformative potential. First, these technologies can drive energy decarbonisation by enabling the integration of renewables, advanced energy storage, and smart grid systems. Second, they can foster material and industrial innovation through the use of bio-based composites, additive manufacturing, and circular economy models. Finally, they can facilitate a socio-digital transformation by leveraging data-driven governance and AI-enabled cross-checking and decision-making. Despite their potential, these technologies face significant hurdles, such as ethical considerations, regulatory gaps, and the challenge of integrating them into existing infrastructure. We argue that these innovations are not stand-alone solutions but rather catalysts that require anticipatory governance, interdisciplinary collaboration, and context-specific deployment to truly foster a sustainable, low-carbon future.

INTRODUCTION

Transformative technology solutions are required in response to the ongoing acceleration of climate change, resource depletion, and growing inequality (Du Pisani, 2006). While the United Nations Sustainable Development Goals (SDGs) provide a guiding framework, achieving them requires rapid innovation across energy, materials, digital systems, and governance (Bogdanov et al., 2021). Cutting-edge technologies, such as green hydrogen, AI, and additive manufacturing, have the potential to transform resource cycles, governance, and production systems (Sakin & Kiroglu, 2017; Lotfabadi, 2015). Yet, realising this potential necessitates careful attention to their environmental footprints, ethical implications, and infrastructural integration (Hu & Milner, 2020; Walzberg et al., 2021). This paper presents a comprehensive review of these emerging technologies, assessing their transformative potential and systemic limitations.

METHODOLOGY

This review synthesises findings from recent peer-reviewed articles, systematic and meta-literature reviews, and case studies published between 2019 and 2025. Searches were conducted across academic databases such as ScienceDirect and MDPI (Walzberg et al., 2021). Key themes were organised into thematic clusters, with an emphasis on cross-disciplinary integration and governance frameworks. The paper adopts a critical lens, interrogating not only technological opportunity but also scalability, ethics, and sustainability performance (Hu & Milner, 2020).

MATERIAL AND MANUFACTURING INNOVATION

Additive Manufacturing and 3D Printing – Additive manufacturing (AM), or 3D printing, enables complex geometry fabrication layer by layer, reducing material waste and enabling design flexibility (Gopal et al., 2023). Systematic reviews indicate AM to support SDGs through circular economy principles, lifecycle assessment, and resource reduction. Empirical assessments show that AM fosters environmental, economic, and social sustainability—but energy consumption remains a major concern (Khalid & Peng, 2021) . Another review underscores AM's role in lean, green manufacturing; while AM contributes to reduced supply chains and resource efficiency, limitations remain, such as high energy use and material constraints (MDPI, 2022). 3D concrete printing, a subset of AM, illustrates the technology's construction applications: by extruding specialised concrete mixtures, structures are built without formwork, and thixotropic behaviour plus

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fibre reinforcements improve buildability and strength (MDPI review).

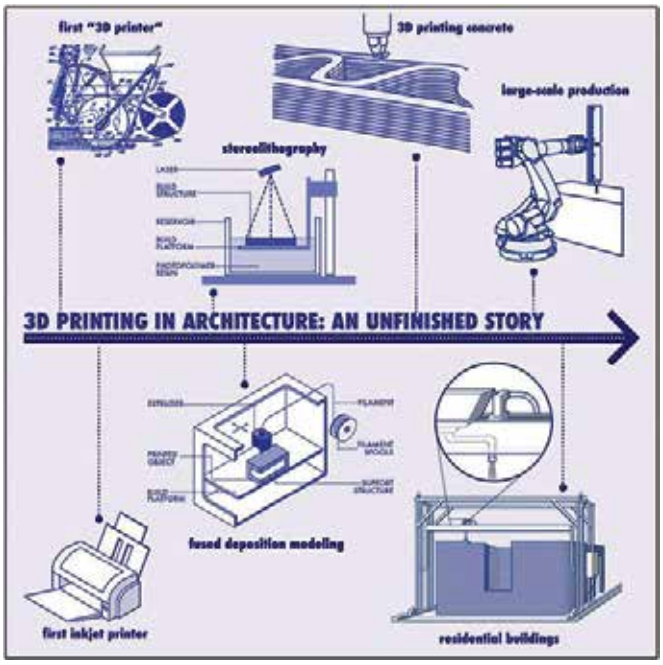

Fig. 1: Working principle of 3D Printing in Architecture

Bio-based and Ecologically Designed Materials – Biodesign leverages living systems to create regenerative, sustainable materials. Mycelium composites, algae-based polymers, and bacterial cellulose represent biodegradable alternatives to plastics and foams. These materials offer benefits such as lightweight, fire resistance, carbon absorption, and self-healing capabilities, with low-energy fabrication at ambient conditions. Media case studies, like bioconcrete lamps, demonstrate the real-world application of biotech in design (Financial Times, 2024).

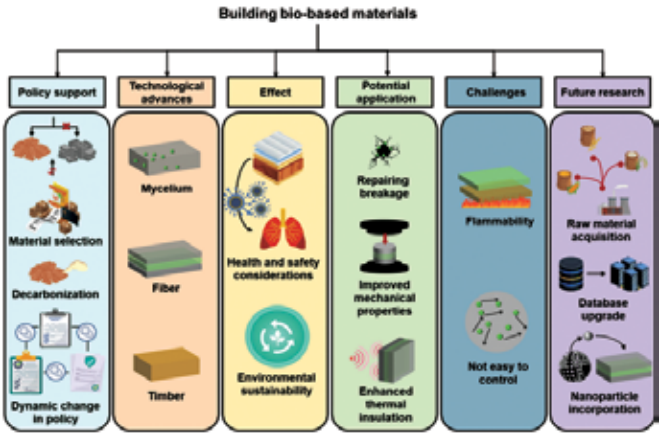

Fig. 2: Systematic diagram of bio-based Building material

DIGITAL TECHNOLOGIES FOR RESILIENT SOCIO-TECHNICAL SYSTEMS

Artificial Intelligence – The integration of Artificial Intelligence (AI), Blockchain (BC), and the Internet of Things (IoT) is fundamentally transforming the design, construction, and operation of buildings, enabling them to function as intelligent, resilient, and resource-efficient systems. Within the built environment, these digital technologies facilitate real-time monitoring, predictive control, and evidence-based decision-making across the building lifecycle. IoT sensors embedded in Building Management Systems (BMS) can continuously measure parameters such as energy consumption, indoor air quality, thermal comfort, and occupant behaviour, enabling dynamic optimisation of heating, ventilation, air conditioning (HVAC), and lighting systems (Kumar et al., 2023). AI further enhances building performance by employing machine learning algorithms to forecast energy demand, adapt system operations to real-time occupancy patterns, and detect anomalies for predictive maintenance, thereby reducing downtime and extending equipment lifespan (Wang & Hong, 2020).

Blockchain – Blockchain strengthens transparency in construction material supply chains, allowing stakeholders to trace embodied carbon, verify sustainable sourcing, and ensure compliance with environmental standards (Turk & Klinc, 2022). When integrated with AI, blockchain supports circular building practices by maintaining digital material passports, tracking reuse potential, and facilitating end-of-life recycling of components (Frontiers, 2024). These integrated platforms also optimise

Fig. 3: Hexagonal socio-technical systems framework (adapted from Clegg 1979; Challenger et al. 2010; Davis et al. 2014).

logistics, supply–demand matching, and asset management within building projects, reducing life-cycle costs and environmental impacts (Springer, 2025). Collectively, AI, blockchain, and IoT establish a foundation for smart, adaptive, and low-carbon buildings, advancing the goals of sustainable urban development while enhancing occupant comfort, operational efficiency, and resilience to climate variability.

ENERGY TRANSFORMATION FOR CLIMATE RESILIENCE

Green hydrogen presents a promising avenue for comprehensive decarbonisation across various industrial sectors, including those heavily reliant on heat, fuel, and large-scale energy storage (Bogdanov et al., 2021). Its intrinsic high energy density makes it particularly suitable for long-duration grid storage, a critical component for integrating intermittent renewable energy sources and ensuring grid stability. Furthermore, green hydrogen plays a pivotal role in decarbonising hard-to-abate industrial processes, such as steelmaking and chemical production, where traditional methods are highly carbon-intensive. By replacing fossil fuels with green hydrogen, these industries can significantly reduce their greenhouse gas emissions, contributing to global climate targets.

Fig. 4: The role of Hydrogen in the Energy Transition

Despite its significant potential, the widespread adoption of green hydrogen currently faces limitations, particularly in the light-duty vehicle sector. Here, battery electric vehicles (BEVs) have gained greater traction due to established infrastructure and consumer familiarity. However, the broader uptake of green hydrogen in other sectors and for a wider range of applications is heavily dependent on the development of supportive infrastructure and comprehensive system integration. This includes the establishment of robust production facilities utilising renewable energy sources, efficient transportation and distribution networks, and the integration of hydrogen technologies into existing industrial processes and energy systems. Overcoming these challenges will be crucial for green hydrogen to fulfil its role as a key enabler of a low-carbon economy (Bogdanov et al., 2021).

GOVERNANCE FRAMEWORKS AND ETHICAL CONSIDERATIONS

According to the EU's Horizon 2020 framework, Responsible Research and Innovation (RRI) emphasises four key areas: societal engagement, ethics, gender equality, and transparency (Responsible Research and Innovation). Applying this framework to frontier technologies ensures that innovations align with societal values, minimise risks, and empower stakeholders. Technologies like additive manufacturing (AM) and renewable energy systems face specific challenges, such as resource extraction, high energy consumption, and end-of-life recycling. For instance, the energy-intensive hardware used in AM, or the mining of lithium and cobalt for batteries, poses sustainability risks. Addressing these risks requires the integration of circular economy strategies and comprehensive lifecycle planning.

Fig. 5: A Governance Framework for Generative AI Management

DISCUSSION

This review highlights that frontier technologies hold significant promise for sustainable development. Their impacts hinge on responsible governance, systemic integration, and lifecycle stewardship. AM and biodesign can reduce waste and emissions, but energy use and scalability must be mitigated. Digital technologies can optimise operations yet require equitable access and governance. Green hydrogen and QC offer decarbonisation pathways, although infrastructural and technological maturity are challenges.

Successful deployment of these technologies requires:

- Interdisciplinary research and collaboration, engaging engineers, social scientists, policymakers, and communities.
- Lifecycle and circular economy integration, embedding product and system design within recycling, resource-efficient frameworks.
- Governance innovations such as RRI and anticipatory regulation to ensure ethical deployment and stakeholder inclusivity.
- Context-sensitive deployment, aligning technology adoption with local infrastructures, cultures, and capacities.

CONCLUSION

Frontier technologies—including additive manufacturing, digital systems, biodesign, green hydrogen, and quantum computing—represent transformative opportunities for advancing sustainable development in the built environment and across socio-technical systems. Their capacity to reduce carbon intensity, enhance resilience, and enable circular resource flows demonstrates significant potential. However, realising these benefits depends on proactive governance, integration across existing infrastructures, and rigorous attention to lifecycle impacts to avoid unintended trade-offs.

Building on these insights, a forward-looking research and policy agenda is essential. Priority areas include conducting comparative lifecycle assessments to evaluate emerging technologies against conventional alternatives, developing policy frameworks informed by Responsible Research and Innovation (RRI) principles, and designing pilot projects that embed technological innovation within circular economy models and participatory governance. Equally critical is fostering international and regional knowledge-sharing networks to balance global innovation with local adaptation and equity. By advancing these priorities, frontier technologies can be harnessed not as isolated technical fixes but as catalysts for systemic, resilient, and inclusive development pathways that remain aligned with planetary boundaries.

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VIKSIT BHARAT @ 2047 – SUSTAINABLE INFRASTRUCTURE

USHA BATRA*

Abstract

Viksit Bharat or Developed India aims to transform India into a fully developed nation by 2047, marking 100 years of independence. A crucial aspect of the 2047 Viksit Bharat vision is the development of world-class infrastructure to drive sustainable growth, improve climate resilience, and enhance the standard of living for all. Infrastructure development is a vital component of India's vision for Viksit Bharat, which aims to transform the country into a developed nation by the centenary of its independence. A well-planned and efficient infrastructure network supports economic growth, improves connectivity, and enhances the quality of life. Key focus areas include transportation such as roads, railways, ports, and airports, urban and rural development, energy, digital connectivity, and industrial corridors.

The government is also further dedicated to enhancing its non-fossil energy capacity to 500 GW and meeting 50% of its energy needs from renewable sources by 2030. It aims to reduce total projected carbon emissions by one billion tonnes, lower the economy's carbon intensity by over 45%, and achieve net-zero emissions by 2070.

Smart and resilient cities, climate adaptation technologies, energy efficient buildings, Sustainable construction materials and technologies and innovative practices to reduce environmental impact and enhance efficiency play a crucial role in this shift.

Finally strategic reforms and innovative financial mechanisms that can effectively mobilize long-term capital are a must to fulfill the targets of Viksit Bharat.

INTRODUCTION

Viksit Bharat 2047 is a vision of Prime Minister Narendra Modi to make India a developed country by the year 2047, when India will celebrate its 100th year of independence. According to this vision, India will achieve a $30-trillion economy, provide a pucca house and piped water to every citizen, empower women farmers with drones, increase the number of affordable medicines through Jan Aushadhi Kendras, and adopt green and sustainable growth policies. Viksit Bharat 2047 also aims to overcome the colonial legacy, strengthen India's geopolitical position, and enhance its diplomatic relations with other countries.

Achieving green and sustainable growth by adopting clean and renewable energy sources, reducing carbon emissions, enhancing biodiversity conservation, and mitigating the impacts of climate change, India has committed to increasing its non-fossil energy capacity to 500 GW by 2030, and achieving the target of Net Zero by 2070.

India's population is expected to reach 950 million by 2050 as per HT dated 24.7.25. As only half the infrastructure needed to support this growth has been built, it in itself is a challenge as well as an opportunity. Hence a dedicated national urban resilience program along with financing strategy needs to be looked into.

Vision of Viksit Bharat can only be realized through Viksit states and that aspiration has to reach the grassroot level i.e. to each district, block and village. For this, each state has to create a vision for 2047.

To fulfill the Viksit Bharat Mission, a multifaceted and strategic approach is essential, combining visionary planning with grassroots implementation. In line with this, Government has launched PM Gati Shakti, a comprehensive digital platform that integrates the efforts of multiple ministries for seamless infrastructure planning and execution, enabling real-time coordination, reducing project delays, and promoting cost-effective development.

As pear HT dated 23.07.2025, World bank report says that India needs investment of $2.4 tn by 2050 for climate resilient infrastructure. It also clears that current municipal spending is well below the investment needed for climate resilient, low carbon intensive infrastructure in Indian cities which face a triple threat of flooding, water scarcity and heat.

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Report estimated that between 2022-2070 over 144 million dwelling units will be needed, over twice the existing housing stock. This would require additional and timely climate resilience measures like risk assessment planning and investing in resilient infrastructure and services including early warning systems with particular focus on vulnerable areas.

KEY PILLARS OF VIKSIT BHARAT

1. Economic Growth: Increasing the GDP through manufacturing, digital economy, and services and Creation of job opportunities through startups, MSMEs, and industrial expansion.
2. Infrastructure Development: Building smart cities, expressways, high-speed railways, and digital infrastructure and Enhancing rural and urban connectivity.
3. Education, Health and Social inclusion: preparing youth for future-ready skills through vocational training, expanding digital health services and insurance schemes, empowering women, youth, and marginalized communities.
4. Digital and Technological Advancement: Promoting AI, 5G, semiconductor manufacturing, and other emerging technologies and encouraging innovation and R&D.
5. Environmental Sustainability: Promoting green energy (solar, wind, hydrogen) and Ensuring water conservation, afforestation, and climate-resilient agriculture.
6. Good Governance: Transparent, accountable, and tech-enabled governance and reducing bureaucratic inefficiencies.

To fulfill the objectives, India needs to do the followings:

i. India needs to fulfill the renewable energy target of 500 GW by 2030 (solar, wind, hydro), expand green hydrogen production for industrial decarbonization, promote electric mobility and battery storage and modernize grids for renewable integration by 2070.

ii. Implement Transit-Oriented Development (TOD) in urban planning, design roads, bridges, and urban infrastructure to withstand extreme heat, floods, and cyclones, Promote use of recycled construction materials and encourage prefabrication and modular construction, promote green buildings, energy-efficient retrofits, and smart city missions, 100% implementation of waste segregation, circular economy practices, and zero-landfill goals along with development of blue-green infrastructure (urban forests, wetlands restoration).

iii. Adopt climate-smart farming practices, promote organic, natural farming, and efficient irrigation using digital agri-tech platforms for precision input use and enhance farmer incomes through value chains and agro-processing for climate-resilient and productive agriculture.

iv. Promote energy efficiency in MSMEs and heavy industries and develop green industrial corridors integrated with logistics for green industrial development.

v. Electrify railways and public transport fleets, upgrade to semi-high-speed and high-speed rail corridors for modal shift from road to rail, expand metro networks, bicycle highways, and pedestrian pathways, along with development of multi-modal logistics parks to reduce freight emissions for sustainable infrastructure & transport.

vi. Implement rainwater harvesting, rejuvenate rivers, lakes, wetlands, and promote integrated watershed management for water & natural resource management.

To achieve the above, implementation mechanisms are PM Gati Shakti for integrated infrastructure planning, viability gap funding and incentives for renewables and green industries, national missions (Hydrogen, Bio-energy, Electric Mobility), data-driven monitoring such as remote sensing, IoT, AI for sustainability KPIs., and capacity building of local governments and communities.

INFRASTRUCTURE DEVELOPMENT AND SUSTAINABILITY – BACKBONE OF VIKSIT BHARAT

Infrastructure development is the backbone of a nation's progress. Hence building modern, inclusive, and sustainable infrastructure is most essential. The infrastructure development will enhance connectivity, foster economic growth, improve quality of life, and make India globally competitive but sustainability is a necessity to ensure that India's growth is resilient, inclusive, environment-friendly, and beneficial to future generations. Integrating sustainability in development will ensure clean air,

safe water, and ecological balance, essential for health and resilience. India is highly vulnerable to climate risks like heat waves, floods, and droughts. Sustainability through green infrastructure, renewable energy, and resilient planning will mitigate these impacts while sustainable urban planning will ensure citizen well-being with better mobility, green spaces, and waste management. However, all the infrastructure has also to be durable and sustainable for the disasters.

Natural disasters, poor quality control and construction Practices, aging infrastructure and lack of maintenance, corruption, climate change and urbanization including floods, extreme temperatures, and cyclones are the major reasons of infrastructure failure (Fig 3).Several major bridges have collapsed leading to fatalities and disruptions in transport links in last few years. Even buildings' collapses due to structural failures in India have resulted in an average of 5 deaths per day between 2018 and 2022, primarily in residential sector. Approximately 2,500 buildings collapse in India every year.

Infrastructure Failure

As per HT dated 24.07.25, in 2024, National Highway recorded 52,609 fatalities and 53,372in 2023, inviting critical focus for safety interventions.

Heavy rainfall and flooding frequently cause damage to roads, leading to disruptions and safety concerns. Huge amount of money and time goes into repair / reconstruction apart from loss of lives and property. Even now, monsoon landslides are playing havoc in Himachal and Uttarakhand hence these challenges need to be addressed meticulously. After unabated development, Government is working with states to identify unstable hill slopes and to develop appropriate evacuation process.

Updation of Master Plans

All the master plans are not prepared for 2047 and to be updated for the infrastructure development required for Viksit Bharat 2047. For example, Delhi is the most populous city of the nation and has at least 2 million people living in slums. It also struggles for traffic congestion, poor air quality, worsening pollution, waste management and natural resource degradation. Therefore, the Master Plan for Delhi focuses on reducing pollution, building green-blue infrastructure that will include natural areas, parks, wetlands, water bodies, and promoting urban farming. The plan promotes multimodal integration ensuring smooth connectivity between metros, buses, e-rickshaws, bicycles, and pedestrian pathways. It encourages the use of public transport to reduce dependency on private vehicles, aiming to tackle issues like traffic congestion and air pollution. Transit-Oriented development (TOD) is a key strategy that encourages high-density, mixed-use development around transit hubs to promote walk ability and reduce travel distances[5].

Draft MPD 2041 has already been prepared. After implementation of MPD-2041, nearly 70% of Delhi's land (1,04,000 hectares) will be urbanized for residential, commercial, industrial, public, and semi-public uses. Around 30% (44,000 hectares) will remain non-urbanizable, which includes rural areas, agricultural land, Yamuna river zone and floodplains, forests and protected ridge areas, green belts, city greens, and ecological conservation zones. MPD 2041 limits further urban expansion to protect ecological assets for sustainability and resilience thereby shifting focus towards redevelopment, densification, and efficient land use within existing urban limits after 2041[5]. Almost similar would be the situation in other metro cities and after few years other small cities as well, necessitating robust infrastructure and urban planning.

Modernization of Railways, Highways and Airports for Viksit Bharat

Railways have already taken up some projects like Mumbai-Ahmedabad bullet train and Vande Bharat trains but many are yet to be taken up such as high-speed rails, semi-high-speed trains, electrification of all routes to reduce diesel use and carbon emissions., smart stations with better amenities, digital boards, automatic signaling and modern train control systems for safety and better scheduling, and upgraded freight corridors to boost logistics and reduce congestion on passenger routes. Highways to include will be development of expressways like Delhi-Mumbai Expressway and economic corridors, smart traffic management systems using sensors, AI, and real-time data, roadside amenities, electric vehicle (EV) charging stations, and green landscaping, use of drones and GIS for monitoring construction and maintenance and wider roads with

access control and grade-separated interchanges for safety and speed.Ports to be included are implementation of the "Sagarmala Programme" for improving efficiency and port connectivity, mechanization and automation of cargo handling and logistics, development of smart ports using AI, block chain, and IoT, decongesting major ports by developing satellite ports and inland waterways and enabling port-led industrial zones for integrating trade with industry. Airports to include are expansion and construction of new airports, heliports, and modernization of existing terminals with digital check-in, biometric boarding, and AI-enabled security, green airport initiatives using solar energy, waste management, and sustainable construction, boosting air cargo infrastructure with cold chains and logistics hubs and enhancing air traffic control systems for safer and efficient operations.

Smart Cities for Viksit Bharat

A smart city uses technology, data, and citizen-centric planning to improve urban life quality, infrastructure, and services. Smart cities mission covered 100 cities, focusing on area-based development (retrofitting, redevelopment, green field projects) and pan-city solutions like intelligent transport, smart water management but Indian smart cities are not yet "holistically smart cities" with inclusive, sustainable, integrated urban development at citywide scale. They represent some important steps towards smart urban governance and infrastructure but need stronger integration of green infrastructure and climate resilience, social inclusivity, citywide transformation (beyond small retrofitted areas), and data privacy frameworks. They are nowhere comparable to the holistic, integrated, and inclusive models of Singapore, Seoul, or Amsterdam. To achieve Viksit Bharat goals, India needs to scale smart city solutions citywide, embedding sustainability and inclusivity as core goals, not mere add-ons and strengthen citizen participation and data privacy frameworks to achieve the successful mission of smart city mission.

ENERGY REQUIREMENT FOR VIKSIT BHARAT AND ITS ROADMAP

India's power demand is projected to reach 708 gigawatts (GW) by 2047. To meet this demand, a fourfold increase in power generation capacity to 2,100 GW will be necessary. Chairperson CEA presented roadmap for achieving 1200 GWof solar power, over 400 GW of wind power by 2047, focusing on hydro pump storage plants, nuclear power and modernizing the grid infrastructure during 2-day conclave on 14 oct 2024[1] .

As per Economic times 29 Jan 2025 –Now the earlier vision of 500GW by 2030 is being revised to a longer-term vision which aims for 1,800 GW of renewable energy capacity by 2047, according to Union Minister Prahlad Joshi. He said RE capacity has surged almost 200 times from 75.52 GW in 2014 to 220 GW today.

CEA further projects the requirement for energy storage to reach 2380 GWh by 2047, comprised of 90 GW from Pumped Storage Projects (PSP) and 230 GW from Battery Energy Storage Systems (BESS). This expansion is crucial for integrating a larger share of renewable energy into the grid and achieving India's ambitious renewable energy targets.

Renewable energy sources have hardly been tapped so far as all renewable energy sources together have the potential to provide 3,078 times the current global energy needs, of which solar energy 2,850 times, wind energy 200 times, biomass 20 times, geothermal 5 times, wave-tidal energy 2 times, and hydropower 1 time and in shown in Fig.1[8].

Solar potential, estimated by India's National Institute of solar energy is around 750 gigawatts (GW) based on the assumption that 3% of wasteland in each state can be used for solar power projects / solar parks[3]. Solar panels have also been used as sharing over fields, canals, rivers etc serving dual purpose of solar power along with protection and reduced water evaporation and experimented on train, cars, aircraft, building facade and roof tile, solar trees, floating solar plant, solar paneled roads etc. (Fig 3)[8]. Rajasthan has maximum potential for solar, followed by J&K, Maharashtra, MP, Andhra, Gujarat, HP, Odisha, Karnataka and UP.

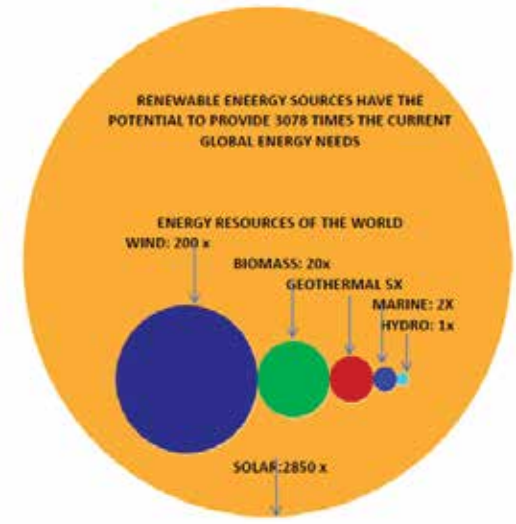

Fig. 1: Renewable energy sources potential

Source: RE-thinking 2050, (www.erec.org)

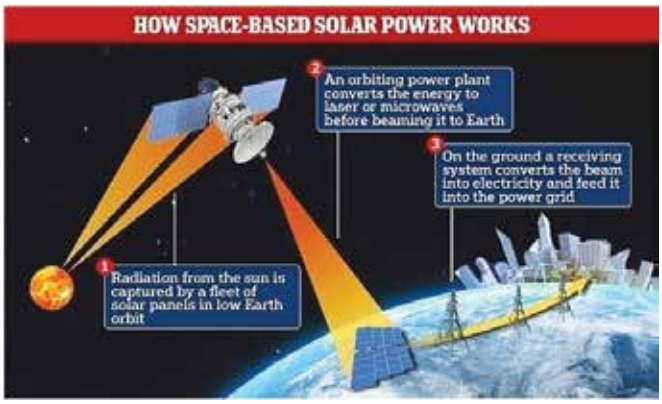

Fig. 2: Beaming solar energy from space to earth

Fig. 3

Solar Energy from Space to Earth

As per HT dated 6.7.2025 – In just one second sun releases enough energy to meet humanity's need for 6,12,900 years. Only a fraction of that energy reaches the top of atmosphere above earth. Then nearly a third of this energy is either absorbed by the ozone layer or reflected by clouds, aerosols and shiny surface. A silver (with enough energy to last 4400 years) reaches the planet surface which the planet in turn releases as heat. Some of this heat radiates back into space, but a lot of it is trapped by greenhouse gas and clouds. Japan is leading the world in terms of renewable energy, making solar panels mandatory for all buildings not later than 2030. New solar panels are 1000 times stronger than silicon. It is also pioneering the concept of beaming solar energy from space to earth through its OHISAMA project. This project involves a satellite equipped with solar panels that will collect sunlight and convert it into microwave energy, which is then beamed back to earth and converted into electricity (Fig.2). This technology offers the potential for a 24/7 clean energy source, regardless of weather conditions or time of day, and could be particularly beneficial in remote or disaster-stricken areas. The first test satellite is planned for launch in 2025[2]. In case of successful results and technology transfer to other countries, it could be a game changing plan for solar power and may not require to explore other sources.

CHALLENGES TO ACHIEVE VIKSIT BHARAT

Climate Change

The Paris Agreement aimed to limit global warming to well below 2°C above pre-industrial levels, with efforts to limit it to 1.5°C. Year 2024 was the first year when temperatures exceeded 1.5°C above pre-industrial levels[4], breaching the critical threshold set by the Paris Agreement. Although this was a single-year event, but a worrying trend and the potential for more frequent breaches of the 1.5°C limit in future.

In HT dated 24.7.25 world court said - Climate change is urgent and existential threat. National climate plans must be of the highest ambition and collectively maintain standards to meet the aims of 2015 Paris agreement that include attempting to keep global warming below 1.5°C as under international law the human right to clean, healthy and sustainable environment is essential for the enjoyment of other human rights.

Flooding in Urban India

As per HT dated 21.07.25, many cities in India are near deep in rainwater during pre-monsoon season. Rainwater is meant to take its natural course flowing from upstream to downstream and falling into a lake, river or sea or sinking back into the earth. However, when linear infrastructure such as rail track, roads or buildings intercepts the natural flow or concrete surface and prevents absorption, flooding occurs. During heavy rain last year, water levels in the Yamuna did not rise yet south and central Delhi inundated.

Across many cities, mindless overbuilding has been done. WRI- India found that between 2000 and 2015, the buildup area in 10 most populous Indian cities increased on average by 47% and 134% within 0 to 20 km of the city centre and 20 to 50 km periphery respectively. Simultaneously the blue cover (water bodies) decreased by 15%. The study also found that 44% of this new development is located in zones with high or very high recharge potential and an estimated 300 billion of water per year are now diverted away from underground aquifers. A US - specific study indicates that even at 1% increase in Built-up area results in 7% increase in the extent of flooding.

Many cities have common channels for stormwater and sewers. Indian cities don't have a separate utility duct to put water supply lines, power lines, data fiber etc. They use storm drain as an easy conduit. If the older cities suffer from legacy drainage issues, the newer towns have grown without the basics. Multiple jurisdictions of drains compound the problem. In Delhi, nine agencies are involved in drain management. If the flood and irrigation department drains are not clean, the water from public works department will backflow. When PWD drains are blocked, the MCD drains backflow.

Indian cities prepare for the monsoon mess throughout the year by dumping tons of garbage, construction waste and domestic sewage into storm water channels. Before the monsoon, the road owning agencies clean these choked drains leaving them on the roadside. During the first shower, the muck is back in the drains.

Therefore, bold reforms in urban governance are required. As per HT dated July 14, 2025, Indian cities urgently need governing structures that are integrated, long term and people centric. Bengaluru launched a bold experiment in urban governance by creating a Greater Bengaluru Authority (GBA) encompassing Bangalore development Authority (BDA) water supply and Sewerage Board (BWSSB), Bengaluru Metropolitan transport Corporation (BMTC), solid waste management Corporation and Bengaluru Metro rail Corporation Limited to re-align metropolitan governance, moving beyond traditional models that have long struggled with fragmented responsibilities and poor coordination to resolve its core challenges e.g. traffic congestion, water management and unplanned growth. In case this model is successful, then it can be followed in other cities as well. Apart from this, urban planning needs to be taken care strongly rejecting / modifying proposals which disrupt most important / priority fundamentals of planning and maintenance.

The solution of drainage problem appears to be hydrological mapping of cities to be given priority to understand how water flows on the surface and through the drainage network and streamlining the finances and tendering processes are protocols to operationalize nature-based solutions. Cities like Mumbai where every inch of land is extremely valuable, there is no space for NBS apart from government land, forest land, the national park and salt pans which has prompted to design NBS considering existing gardens and grounds. Mangroves and salt pans also act as great detention and retention areas for flood water. Mumbai is also working to develop a flood management Plan.

A sponge city is another possible solution. It is urban design approach focused on enhancing a city's capacity to absorb, store, and filter rainwater, thereby mitigating flooding and improving water management. Several Indian cities are exploring or implementing sponge city concepts to address issues like urban flooding and water scarcity. These initiatives involve incorporating features like permeable pavements, green roofs, rain gardens, and other water-retention systems. Indian cities exploring sponge city systems are Chennai, Bengaluru, Ahmedabad, Hyderabad, Visakhapatnam, Rajahmundry, and Kakinada.

Financial Resources, Technologies and Unemployment

Paris Agreement stipulated that developed countries should take the lead in providing financial resources and technology transfer to developing countries to mitigate and adapt to the impacts of climate change[6]. A key aspect of the agreement is the collective goal of mobilizing USD 100 billion per year in climate finance by 2020, and continuing this through 2025. While this goal was met in 2022, it was achieved two years later than initially targeted. Technology transfer from developed to developing countries faces significant challenges despite international commitments. Technology transfer is a complex process with significant potential to contribute to sustainable development in developing countries.

Artificial intelligence, Robotics and 3D printing technology can also pose challenges. As per HT dated 16.7.25, official unemployment rate is 5.6%, and we are entering an era where knowledge work itself is under threat. AI may not just replace jobs, it may hollow them out, change their nature, widen inequalities between the AI haves and have nots. We need to ensure that AI becomes a force for inclusion rather than exclusion, be it in jobs, agriculture, manufacturing or other fields. Similar would be the case in Robotics and 3D Printing. Technological advancements may create new problems of unemployment unless mode of inclusivity is meticulously worked out.

India's progress is also held up due to deep endemic corruption, lack of judicial reforms, dysfunctional municipal corporations and a compliance raj that adds layers of costs in terms of both money and times. World economic forum pins bribes at 50% of the project cost in infrastructure and real estate.

India's R & D spending is under 0.7% of GDP, lowest in the world despite being 5th largest economy[7]. Us (3.5%), China (2.7%), smaller economies e.g. South Korea (5%), Brazil (1.2%) limiting our scientific ambition. It hinders India's ability to compete globally in terms of innovation and technological advancement.

Boom in digital services / transactions has given attractive target to cybercriminals. As per HT dated 23.07.25 Rs 22000 cr. is lost to cyber frauds in 2024, with over 2.2 million cybercrime incidents, a 42% increase from 1.6 million cases in 2023. How this issue can be resolved is a matter of great concern.

CONCLUSION

Viksit Bharat vision is the development of world-class infrastructure to drive sustainable growth, improve climate resilience, and enhance the standard of living for all. It aims to reduce total projected carbon emissions by one billion tonnes, lower the economy's carbon intensity by over 45%, and achieve net-zero emissions by 2070.

To fulfill the Viksit Bharat Mission, a multifaceted and strategic approach is essential, combining visionary planning with grassroots implementation.

Infrastructure development is the backbone of a nation's progress and sustainability is a necessity to ensure that India's growth is resilient, inclusive, environment-friendly, and beneficial to future generations. Hence India needs to Implement Transit-Oriented Development (TOD) in urban planning, design roads, bridges, and urban infrastructure to withstand extreme heat, floods, and cyclones, promote use of recycled construction materials and encourage prefabrication and modular construction, promote green buildings, energy-efficient retrofits, and smart city missions, 100% implementation of waste segregation, circular economy practices, and zero-landfill goals along with development of blue-green infrastructure.

Viksit Bharat mission is an opportunity but there are many challenges on its path of achievement.

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PROTOTYPING REDEVELOPMENT FOR STRATEGIC URBAN DENSIFICATION

MITU MATHUR*

Abstract

India's urban cores are witnessing mounting pressure from population growth, ageing infrastructure, and fragmented development patterns. These challenges are further compounded by rising energy demands, infrastructure lag, ecological degradation, and increasing peripheral development. This research positions strategic densification of urban cores as an opportunity to reimagine urban growth through integrated, design-led frameworks that prioritise resilience, inclusion, and ecological balance. It investigates the redevelopment of low-density neighbourhoods as a replicable approach to future-ready urbanism.

Drawing on case studies of Sarojini Nagar (250 acres) and Netaji Nagar (110 acres) neighbourhoods in Delhi, originally developed as low-rise government housing post-independence, the study examines how their transformation into high-density, mixed-use precincts comprising residential, commercial, and office typologies demonstrates the potential of integrated planning. Anchored by transit-oriented connectivity with a pedestrian-first approach, passive design strategies, and low-carbon construction technologies, it will highlight how redevelopment can optimise land use, reduce infrastructure stress, and foster self-sufficient communities.

Ultimately, the research positions redevelopment not merely as a tool of renewal but as a future-forward prototype to design climate-responsive micro-urbanisms that embed civic infrastructure, public amenities, and environmental consciousness into everyday urban life. By foregrounding inclusivity, sustainability, and scalability in the design process, the research highlights how redevelopment can offer a replicable design and policy prototype for building compact, connected, and culturally rooted urban ecosystems.

INTRODUCTION

India stands at the cusp of an unprecedented urban shift. By 2047, nearly half of the country's population is projected to live in urban areas (NITI Aayog, 2021), placing enormous pressure on cities that are already struggling with ageing infrastructure, fragmented land use, and declining livability. In dense metropolises like Delhi, vast tracts of centrally located government housing remain under built, even as peripheral sprawl accelerates, driving longer commutes, ecological degradation, and unsustainable infrastructure costs.

Amid this dual crisis of under utilisation and overexpansion, strategic urban redevelopment emerges as a critical pathway, not just for upgrading infrastructure, but for fundamentally rethinking how Indian cities grow. Rather than defaulting to unplanned vertical growth, a design-led approach to strategic densification enables cities to intensify land use while embedding social infrastructure, walk ability, and environmental resilience into the urban fabric.

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This research examines how large-scale redevelopment of public housing estates can serve as a replicable model for such transformation. It draws on two central Delhi neighbourhood redevelopments—Sarojini Nagar and Netaji Nagar—to explore how compact, mixed-use, and climate-responsive communities can be created within existing urban footprints. In doing so, the paper offers a framework for reimagining Indian urbanism through the lens of integrated, inclusive, and future-ready development.

LITERATURE REVIEW

India's urban cores face a complex set of challenges, including low-density land use, ageing housing stock, overstretched infrastructure, and worsening environmental conditions, all of which demand a structured approach to redevelopment. According to the Ministry of Housing and Urban Affairs' Urban and Regional Development Plans Formulation and Implementation Guidelines (MoHUA, 2015) and the Master Plan for Delhi 2041 (Delhi Development Authority [DDA], 2023), several centrally located government housing colonies continue to operate at floor area ratios (FAR) as

low as 1.2–1.5, despite occupying prime land and being well-connected to transit infrastructure. This results in severe underutilisation of urban land and exacerbates sprawl on the periphery, leading to longer commutes, higher infrastructure costs, and ecological degradation.

Recent data from the National Institute of Urban Affairs (NIUA) and NITI Aayog show that over 60% of urban growth in Tier 1 cities is happening in peripheral areas, far from job centres and public transport (NIUA & NITI Aayog, 2021). This sprawling growth has increased dependence on private vehicles and stretched service delivery, undermining sustainability goals. For example, Delhi's vehicle count crossed 1.2 crore in 2023 (Transport Department, Government of NCT of Delhi [GNCTD], 2023), further contributing to urban heat island effects and poor air quality.

Unplanned densification has also created stress on civic infrastructure. In cities like Bengaluru and Gurugram, high-rise developments have outpaced infrastructure provisioning, leading to water scarcity and traffic congestion (Central Public Health and Environmental Engineering Organisation [CPHEEO], 2022). At the same time, dilapidated housing stock in urban cores continues to pose safety risks—Ahmedabad's municipal survey in 2022 identified over 1,100 buildings as structurally unsafe, and Mumbai's Brihanmumbai Municipal Corporation flagged 21% of its old, cessed buildings as needing urgent repair (Indian Express, 2022).

Moreover, the environmental costs of poorly planned redevelopment are evident. A 2021 study by the Centre for Science and Environment (CSE, 2021) revealed that urban green cover declined by nearly 30% in core areas of cities like Hyderabad and Pune between 2000 and 2020. Redevelopment projects that overlook ecological integration often increase runoff, heat stress, and energy demand. While policy frameworks such as the National Transit-Oriented Development Policy (MoHUA, 2017) and guidelines under GRIHA and the Energy Conservation Building Code (Bureau of Energy Efficiency [BEE], 2017) advocate integrated and sustainable urban redevelopment, very few built examples in India demonstrate this holistically. Projects often fall short in combining high-density housing with climate-responsive design, walkability, and civic infrastructure.

This research responds to this critical gap by examining two large-scale redevelopment projects in Delhi—Sarojini Nagar and Netaji Nagar—as demonstrative examples of how strategic densification can be spatially, socially, and environmentally integrated. These cases are viewed as evolving urban prototypes that reflect a layered design response to the urgent challenges of contemporary Indian cities. By embedding density within a framework of transit accessibility, ecological sensitivity, and community-oriented infrastructure, they offer a compelling basis to articulate a scalable and replicable model of urban regeneration.

RESEARCH FRAMEWORK

India's urban cores face a unique paradox: while land remains severely constrained, large pockets of under utilised government housing colonies sit in prime locations. In response to this imbalance, this study poses a central question: How can strategic densification of urban cores through integrated, mixed-use planning, passive design, and modern construction methods contribute to inclusive, sustainable, future-ready, self-sufficient, climate-responsive communities in India by 2047?

This research approaches the question through an integrated framework that evaluates redevelopment not as a technical upgrade, but as a city-making opportunity. It seeks to understand how redevelopment projects can be reoriented to serve long-term urban goals—optimising land use, embedding environmental resilience, enabling equitable access to infrastructure, and strengthening civic life.

The study uses built examples from Delhi's urban core as a lens to interrogate this proposition. These examples, situated within existing urban footprints, illustrate how spatial planning and design decisions can be used to embed walkability, optimise land use, reduce resource consumption, and foster socially cohesive communities. The research does not treat these as finished templates but as evolving prototypes that offer critical insight into how redevelopment can be mobilised as a long-term planning tool for Indian cities navigating complex urban pressures.

METHODOLOGY

This research adopts a qualitative, design-led methodology to investigate strategic urban densification as a response to the spatial and ecological challenges faced by Indian cities. The aim is to evaluate how redevelopment, when approached as a city-making exercise rather than a technical upgrade, can deliver compact, inclusive, and climate-responsive neighbourhoods within existing urban cores.

The research framework draws upon established national guidelines such as the National Urban Policy Framework (2018), the Draft Master Plan for Delhi 2041, the Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines, and environmental rating systems such as GRIHA. These sources inform four interrelated dimensions used to guide the inquiry: land use efficiency, mobility integration, ecological design, and social infrastructure.

The research draws on a range of primary sources, including project material, site layouts, policy guidelines, and observational insights, to understand how redevelopment is being shaped on the ground. It focuses on how planning and design decisions influence the long-term resilience and inclusivity of urban neighbourhoods. Rather than viewing the examples as fixed templates, the research approaches them as evolving examples that highlight both the possibilities and challenges of implementing strategic densification. In doing so, it offers a grounded perspective on how thoughtful design can respond to complex urban pressures and help build more balanced, climate-conscious cities.

CASE STUDY: DEMONSTRATING DESIGN-LED RESPONSES TO URBAN CHALLENGES

Delhi's urban core faces intense spatial and ecological pressure. Central districts record densities exceeding 23,000 people per sq km (Delhi Development Authority, 2021), while the city's built-up area expanded by over 150 sq km between 2000 and 2015. Addressing this condition

Fig. 1: Aerial View of Netaji Nagar Redevelopment

Fig. 2: Aerial View of Sarojini Nagar Redevelopment

demands compact, mixed-use planning that integrates housing, transit, ecology, and community infrastructure. Redevelopment of large, centrally located government housing estates presents an opportunity to demonstrate such strategies. In this context, the redevelopment of Netaji Nagar (109 acres; 2868 GPRA units) and Sarojini Nagar (258 acres; 3967 GPRA units), both located within the Lutyens Bungalow Zone's periphery, offer instructive examples.

RECLAIMING LAND USE EFFICIENCY IN UNDERUTILISED CORES

As urban land values climb, the pressure to use prime land more efficiently becomes critical. One of the key ways strategic densification addresses this is through reconfiguring built form to allow vertical growth while releasing ground for public use. This increases the housing capacity and improves the quality of the urban environment by expanding access to green space.

Netaji Nagar redevelopment, for instance, demonstrates how vertical stacking can be balanced with open space provision. With ground coverage reduced from 23% to 14%, the project allocates over 40% of the site to public greens and landscape buffers. Similarly, Sarojini Nagar redevelopment integrates high-rise residential and commercial blocks while retaining the site's existing road network and tree-lined avenues, preserving urban legibility and shade cover even under increased density. These examples show how densification can work with, not against, urban porosity and livability.

Fig. 3: Masterplan for Sarojini Nagar Redevelopment

Fig. 4: Masterplan for Netaji Nagar Redevelopment

Fig. 5: Built-Up Plan for Netaji Nagar Redevelopment

Fig. 6: Built-Up Plan for Sarojini Nagar Redevelopment

EMBEDDING TRANSIT AND WALKABILITY AT THE CORE OF URBAN FORM

Despite having one of the most extensive metro systems in the country, spanning over 390 km and comprising more than 290 stations, Delhi continues to face challenges related to last-mile connectivity and pedestrian accessibility (Delhi Metro Rail Corporation, 2024). A study by the Centre for Science and Environment (2021) found that over 50% of metro users in the city still depend on motorised transport to access stations, pointing to critical gaps in walkable infrastructure and land use integration.

Strategic redevelopment offers a pathway to embed mobility solutions within the very fabric of urban design. Both Netaji Nagar and Sarojini Nagar are located within 200–300 metres of metro stations (Bhikaji Cama and Sarojini Nagar, respectively), and their planning frameworks support last-mile access. At Sarojini Nagar, the urban layout integrates a commercial spine that connects directly to the metro entry, fostering an active, pedestrian-oriented public realm. Internal mobility in Netaji Nagar is structured around peripheral vehicular loops and internal pedestrian streets, ensuring safety and ease for non-motorised movement. These interventions reflect the design intentions promoted under the National Transit Oriented Development Policy (2017) and Delhi's own MPD 2041, which identifies TOD and walkability as key enablers of sustainable urban transformation.

CLIMATE RESPONSIVENESS AS AN URBAN IMPERATIVE

With surface temperatures in central Delhi now frequently exceeding 45°C in peak summer months and a steady rise in average heat indices, the city faces mounting thermal stress, particularly in its dense, built-up areas (IMD, 2023; NIUA, 2022).

Concurrently, water availability has reached critical levels, with per capita supply dropping below 172 litres per day in several localities (Delhi Jal Board, 2022). These intersecting vulnerabilities underscore the urgent need for climate-responsive redevelopment strategies that mitigate environmental risks while improving urban habitability.

Both cases exemplify how dense redevelopment can embed thermal comfort and ecological resilience into the design of everyday environments. At Netaji Nagar, water-sensitive urban design informs key systems with dual plumbing, rainwater harvesting, and treated wastewater reuse, reducing dependence on municipal supply. Sarojini Nagar incorporates similar hydrological strategies and augments them with high-reflectance materials and rooftop photovoltaic installations, reducing both heat gain and energy consumption. These efforts align with GRIHA 3-star benchmarks and mandates from the Energy Conservation Building Code (ECBC) and Delhi's State Action Plan on Climate Change (GRIHA Council, 2019; ECBC, 2021).

REINFORCING SOCIAL INFRASTRUCTURE AND MIXED-USE URBANISM

A key critique of past redevelopment projects has been the erasure of everyday infrastructure like schools, dispensaries, and markets that sustain community life. Strategic densification challenges this by embedding public infrastructure within the urban fabric, ensuring accessibility and continuity.

Fig. 7: Office Block at Netaji Nagar

Fig. 8: Commercial Block at Sarojini Nagar

In Sarojini Nagar, educational and healthcare institutions are consciously retained in their original locations and integrated into the new layout, supporting continuity for long-time residents. The existing market, one of Delhi's oldest and most frequented, is preserved and enhanced through spatial integration and improved access. In Netaji Nagar, similarly, community halls, local shops, and internal greens are distributed within walking distance of housing clusters, reinforcing local interaction. These design choices reflect the best practices promoted under AMRUT and PMAY-Urban, where infrastructure is not appended post facto, but co-designed into the neighbourhood's physical and social core.

MODERN CONSTRUCTION SYSTEMS AS ENABLERS OF SCALABLE URBAN DENSIFICATION

As Indian cities move toward large-scale urban regeneration, conventional construction methods often fall short, leading to time overruns, material wastage, and inconsistencies in quality. With rising demands on speed, cost-efficiency, and environmental performance, the adoption of modern construction technologies becomes critical to the viability of high-density redevelopment. The Ministry of Housing and Urban Affairs (MoHUA) has already identified this need through initiatives like the Global Housing Technology Challenge and the push for pre-approved "Light House Projects" (MoHUA, 2021), which promote innovative building systems for mass housing.

In this context, the use of monolithic RCC shear wall systems, aluminium formwork, and precast components—as seen in both Netaji Nagar and Sarojini Nagar—represents a scalable construction model. These systems enhance structural integrity, reduce material wastage, and allow faster floor cycles, making them well-suited for dense urban redevelopment. The precision enabled by aluminium shuttering and the modularity of precast elements also streamline façade installation, services integration, and interior finishing, improving both build quality and operational efficiency. Together, these technologies support climate-responsive and cost-efficient construction, and make it possible to

replicate high-density, mixed-use neighbourhoods at scale—a critical prerequisite for mainstreaming strategic densification in Indian urban cores.

Fig. 9: Residential Development at Netaji Nagar

Fig. 10: Residential Development at Sarojini Nagar

KEY INSIGHTS AND IMPLICATIONS

India's urban future hinges not on the quantity of growth, but on its quality of development, on how intelligently we reimagine the core of our cities to respond to their most urgent spatial, ecological, and social stresses. This research underscores that strategic, design-led redevelopment can serve as more than an infrastructural intervention; it can become an urban reset. By embedding density within a framework of walkability, climate responsiveness, and inclusive infrastructure, redevelopment projects like Netaji Nagar and Sarojini Nagar begin to demonstrate what that reset might look like.

A critical insight is the shift from reactive densification to intentional, integrated city-making. These examples affirm that high density need not equate to congestion or alienation. When land-use efficiency is paired with ecological planning, when mobility is designed around pedestrians rather than vehicles, and when public infrastructure is treated as foundational, urban life begins to thrive, even under intensified conditions.

The logic underpinning Netaji Nagar and Sarojini Nagar is transferable to other Indian cities with similar contexts, with ageing government or Public Sector Undertaking (PSU) housing colonies located near transit and infrastructure nodes. Cities like Mumbai, Bengaluru, and Hyderabad possess large tracts of such land that can be reimagined through design-led strategic densification.

However, scaling this model will require regulatory and institutional reform. Agencies such as the Delhi Development Authority (DDA), municipal corporations, and public housing boards must therefore move beyond regulatory compliance to embrace a more collaborative and design-conscious mode of planning, one that treats social infrastructure, housing diversity, and environmental resilience as indivisible components of urban form.

CONCLUSION

As India approaches its centenary of independence in 2047, the urgency to recalibrate the development of its urban cores cannot be overstated. With cities grappling with rapid population growth, ecological stress, and increasingly fragmented expansion, the need for land-efficient, inclusive, and environmentally resilient urban models is critical.

This research paper positions strategic densification not merely as a tool to increase built density but as a transformative urban strategy, where integrated, mixed-use planning, passive design interventions, and modern construction technologies collectively shape compact, future-ready communities. The redevelopment of Sarojini Nagar and Netaji Nagar offers compelling evidence of how such an approach can be implemented at scale without displacing their socio-cultural fabric or compromising ecological values.

Rather than viewing redevelopment as a singular intervention, the paper positions it as a catalytic framework, one that enables systemic transformation across planning, governance, and design practice. As Indian cities confront the dual imperatives of accommodating growth and restoring quality of life, it becomes evident that the future lies not in expanding outwards, but in building smarter within.

The research contributes a replicable framework that bridges the domains of planning policy, environmental responsibility, and urban design. What

emerges is a call for Indian cities to move beyond piecemeal, project-based interventions towards holistic, locally contextual urban regeneration that is adaptable, participatory, and grounded in a long-term vision.

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1. **Administrators:** Members of organized Central or State Government Services, Public Sector Undertakings and Private Sector which are dealing in the construction of buildings holding responsible positions.
2. **Engineers:** (i) Persons holding a degree or equivalent qualification in Civil, Electrical, Mechanical, Public Health and allied sciences of Engineering irrespective of experience. (ii) Diploma holders having 10 years' experience in buildings
3. **Architects:** Persons registered with the Council of Architecture
4. **Planners:** Holding a degree qualification in the Science of Planning or the member of Council of Planners.
5. **Educators:** Holding a professional degree in any discipline of Engineering or a Post Graduate Degree in any other discipline and teaching in an Institution imparting education or training in the field connected with buildings.
6. **Trainers:** Same as for Educator
7. Financiers: Persons holding a degree qualification and dealing in finances for the building industry.
8. Developers: Persons heading firms of Developers engaged in development of Real Estate including construction of housing projects with annual turnover or not less than Rs.2 crores.
9. Builders: Builders & Building Contractors either having a Class I registration with Central or State Government or Central or State Undertakings, or with annual turnover of not less than Rs.2 crores in any one of the last three years.

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