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"CHALLENGES & INNOVATIONS IN URBAN PLANNING & DEVELOPMENT"

July 13-14, 2024
New Delhi

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PRELIMINARY PUBLICATION

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V. R. Bansal
Honorary Secretary,

Indian Buildings Congress
Kama Koti Marg, Sector-VI, R.K. Puram,
New Delhi – 110022
Phone No: 011- 26169531, 26170197
E-mail: info@ibc.org.in, indianbldgscongress@gmail.com
Website: www.ibc.org.in

FOREWORD

Urban planning and development are pivotal in shaping the future of our cities, presenting both significant challenges and groundbreaking opportunities. Rapid urbanization has led to overcrowded cities, placing immense pressure on infrastructure and creating urgent housing shortages. Balancing urban growth with environmental sustainability is essential as cities grapple with air and water pollution, waste management, and energy consumption. Efficient, accessible, and sustainable transportation options are crucial to alleviating traffic congestion and reducing emissions. Rising real estate prices further complicate the provision of affordable housing, especially in major urban centers. Many cities also face the daunting task of modernizing outdated infrastructure, requiring substantial investments. Additionally, urban areas must adapt to climate change impacts, such as rising sea levels, increased flooding, and extreme weather events. Addressing socio-economic disparities and ensuring equitable access to services and opportunities are vital for cohesive urban development. Effective urban governance demands coordination among various stakeholders and the implementation of policies that support inclusive and sustainable growth.

Amidst these challenges, several innovations are paving the way for more sustainable and resilient urban environments. Smart cities leverage technology and data analytics to enhance urban services, improve quality of life, and reduce environmental impacts through smart grids, intelligent transportation systems, and IoT-enabled infrastructure. Innovations in building materials and design, such as green roofs, solar panels, and energy-efficient systems, help reduce the environmental footprint of urban structures. The development of high-speed trains, autonomous vehicles, and expanded public transit networks enhances mobility and reduces reliance on personal vehicles. Mixed-use spaces that combine residential, commercial, and recreational areas create vibrant and walkable communities. Resilient infrastructure, designed to withstand natural disasters and climate change effects, including flood-resistant buildings and adaptive road networks, is essential for future urban resilience. Citizen involvement in the planning process through digital platforms and community workshops ensures that urban development reflects the needs and desires of residents. Increasing green spaces and incorporating urban agriculture boost food security, biodiversity, and recreational opportunities. Finally, promoting energy efficiency and the use of renewable energy sources is crucial for sustainably powering urban areas.

By addressing these challenges and leveraging innovations, urban planners and developers can create cities that are more livable, sustainable, and resilient. This foresight ensures a better quality of life for future generations and a harmonious balance between urban growth and environmental stewardship.

Integrating infrastructure development with comprehensive urban planning and cross-sector collaboration creates cohesive growth. These strategies will lead to more sustainable, resilient, and livable cities for future generations. Let's make living a purpose for all.

(Maj. Gen. Ashok Kumar, AVSM)
President, IBC &
Retd. Dir. General (Works), MES

PREFACE

The Indian Buildings Congress Seminars are like taking a dip in the Triveni that washes out the dirt of obsolescence, absorbs fresh ideas and learning from the academics and the practitioners. As India is moving to become a developed economy by 2047, urbanization shall be its backbone. Accordingly, the focus of the national seminar is “Challenges and Innovations in Urban Planning and Development”.

In this context urban planning and development is confronted with huge challenges ranging from climate and disaster resilience, low carbon and net zero buildings and transport, renewable energy, circularity in construction and resources management. These call for a radical transition towards an urban vision @2047.

New age technology is changing the script of urban planning and development as demonstrated by Smart Cities Mission and PM Gati Shakti Master Plan. Artificial Intelligence (AI), Big Data Analytics. Machine Learning (MI), Deep Learning, blockchain, GIS, GPS Digital Twins, etc. are disrupting the urban processes by smart planning and systems. It is time that new forms of transport, services and urban planning are evolved, which are characterized by online exchange of information, interactions, dynamic networks and floating nodes. Under the Geospatial Policy 2022, Digital Twins provide a technology platform for 3D modelling and virtual representation of an object or a system that uses sensors, drones, 5G Internet of Things (IoT) and industrial IoT (IIot) data. It applies advanced analytics, machine learning and artificial intelligence (AI) to derive real time insight into the performance, operation and sustainability of a project or a city. These cover buildings, energy, low carbon zones and tri-generation energy systems. Global positioning systems, satellite-guided GIS and Digital Twins are making it possible to plan and implement the projects with precision and accuracy (A.K. Jain, C.K. Varma).

India is a signatory of the Sustainable Development Goals of the United Nations that gives thrust towards making cities climate and disaster resilient and sustainable. At the United Nations Conference of the Parties (COP 26, Glasgow, 2021) India committed to raise the non-fossil fuel energy from 160 GW to 500 GW by 2030 and 50% of the power requirement to be met by the renewable and achieving the net zero emissions by 2070 by clean technologies.

At the COP 27 (2022, Sharm-el-Sheikh, Egypt), India reaffirmed its long-term Low Emission Development Strategy (LT-LEDS) by a transition towards renewable energy, and conservation, rational use of fossil fuels, nuclear energy, green hydrogen, fuel-cells, and biofuels. The 28th Conference of the Parties (COP28, 2023, Dubai) agreed to accelerate short-term climate actions and strengthening the sustainability

challenges in the urban sector. This calls for climate conscious and resilient urban development (R. Srinivas, V. Shobhana, Usha Batra, Saurabh Jindal, K. M. Soni, J. K. Gupta, Hitendra Mehta and Ayusha Batham).

The paradigm of development has to synthesize with its humane and social aspects, protecting the rights of the poor and provide them with housing with the basic services (Shailesh Kumar Agrawal et. al, Y. Pramod Kumar Reddy, V. Srinivasan).

New technologies are critical in evolving sustainability solutions with respect to traffic and transport management, urban mobility, waste recycling, conservation of heritage and seismic retrofitting (Pawan Kumar, P. Jyotika, Narender Singh, Devibhuti, Harsh Gupta, B. P. Suneja).

The basis of sustainable development is the mindful production, utilization, and consumption. A low carbon lifestyle is a cluster of habits, embedded in the social behaviour and psychology that promotes the conservation of natural resources and minimizing generation of emissions, wastes and pollution. This requires a change in social norms based on the principles of organicity, non-accumulation (aparigraha), minimalism and slowing down. In this context the Lifestyle for Environment endeavors living in balance with the natural environment, where reuse, waste segregation and recycling are promoted (Harsh Gupta, et. al). Net zero urban development and decarbonisation can also promote creation of jobs, urban variety and gender equity. The tools of digital planning and governance, adoption of micro-climatic passive design approach and intelligent services, optimum use of land and natural resources, and new partnerships are inevitable in this pursuit.

The Technical Committee acknowledges the support of the President and the Executive Committee, IBC. The contribution of its members – Shri Salil R. Shrivastava, Shri I. S. Sidhu, Shri V. R. Bansal, Shri Rajeev Kumar Gupta, Shri N.K. Singh, Deputy Secretary, IBC is appreciated.

(A.K Jain)
Chairman, Technical Committee, IBC &
Former Commissioner (Planning), DDA

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CONTENTS

"CHALLENGES & INNOVATIONS IN URBAN PLANNING & DEVELOPMENT"

TRANSFORMING URBAN INFRASTRUCTURE: DIGITAL TWIN TECHNOLOGY

C. K. Varma*

Abstract

Creation of Urban Infrastructure is capital intensive as well as time consuming. In addition, occurrence of mistakes during conception and execution of the project is very common which are sometimes difficult or impossible to rectify without redoing which again involves sizable cost and time. Moreover, changes driven by technology, climate, social and other factors are to be incorporated in between as a necessity rather than exception due to change in policy framework and narrative set by innovations and challenges. Visualization through a virtual model of the actual creation on ground is therefore the best solution offered by the digital technology through creation of digital twin with scope for amalgamating midway changes also. Digital twin technology thus equips the urban planners with digital model of what is to be developed and constructed as well as changes essentially desirable due to operational necessities and maintenance improvements. The technology thus provides a way to visualization of real-life situations, associated problems, assessment of right kind of solutions and consequent improvements over what is conceived. The outcome from this technology is also thoroughly insightful from sustainability and economical point of view. How this technology works and how this can be employed to the best advantages of urban planners and what challenges are encountered is the subject matter of this paper. Also, what future form it will take and how it will shape the urban policies is also included in the scope of this paper.

INTRODUCTION

PM Gatishakti National Master Plan is one such plan at National level where digital twin technology has been utilized and brings together all concerned departments and state governments. For better coordination and completing the infrastructure work seamlessly in the minimum possible time, digital twin technology is allowing all stakeholders to come together to make accurate near real time decisions.

Thus, digital twin technology provides new frontiers for future cities and all types of connectivity infrastructures which need to be smart, sustainable, all-inclusive and adaptable for future development and futuristic technologies.

SIGNIFICANCE OF URBAN PLANNING

Urban planning is a domain which is largely governed by regulations adopted and imposed by urban local bodies who have the vast powers over allowing various features and restrictions into the urban landscape like type of land usages, type of structures depending upon seismic zone classification, land features, proximity to water bodies etc., type of infrastructure for urban

Fig. 1: PM Gatishakti National Master Plan uses digital twin technology for visualizing the physical, operational and aspects of 'to be planned infra' and 'under planning infrastructure'. Digital Twin allows geospatial integration which is crucial for multi-level coordination.

mobility, digital connectivity, power availability, features for fire and electricity safety and so on. The concept of digitally empowered cities and IoT enabled information about traffic requirements, population needs, water, sanitation and various other indicators for the urban life have paved the way for digitally conceiving the urban habitats first and then allowing and creating the physical infrastructure necessary for urban living. Digital twin technology provides this digital transformation through developing digital or virtual twin model which is accurately

*Former Spl. D.G., CPWD

designed of the physical objects, processes and systems individually or collectively as a whole and is way different than simply simulation. It is thus a virtual reflection of future set-up along with virtual blueprint of what is to be built while including improvement suggested by past practices as well. In a way, Up To Date and To Be Coming representations of a real reality asset for construction, operation and maintenance can be well enabled by this technology.

Combined with multi-angle simulation up to 360 degrees, usage of big data, data analytics, IoT and machine learning capabilities; effect of design changes, user's practices, impact of environmental conditions, and many other important variables can be demonstrated and combined effortlessly by this technology. The need for physical models can thus be obviated thereby reducing time of its construction enabling improvement in quality and eliminating chances of mistakes in the built project. These are some of the essences of this technology which is digitally transforming the urban landscape globally. Urban planning activities are therefore aided, improved and eased significantly via incorporating improved systems into built environments through visualizing different perspectives by virtue of a 3D Virtual model from various angles and under variable environmental conditions.

Fig. 2: The figure depicts virtual model and under construction physical model side by side, with fast urban mobility, net zero and net zero buildings, and digitally secured comprehensive infrastructure

HISTORICAL PERSPECTIVE

The development of this technology over last decades is very interesting. It is pertinent to point out that beginning of this technology can be credited to building of physical models which subsequently took the form of virtual models. Physically duplicated systems were created on ground to match the systems in space by NASA initially. Apollo 13 is an example where the physical model of space conditions was duplicated by NASA. NASA therefore employed the concept of twinning since 1960 for simulation of space conditions on ground.

However, the concept for general use was first reflected in 1991 in a book "Mirror Worlds" by David Galernter. Further, the idea and model of the digital twin was first publicly introduced in 2002 by Michael Grieves. The term "digital twin" finally came to be used by John Vickers of NASA in a 2010 Roadmap Report while prior to it, it was known by different names like virtual prototyping, hybrid twin technology, virtual twin, and digital asset management etc.

What we see now is the outcome of continuous improvement of this technology. It is heartening to note that it is becoming one of the top technology trends since 2017 and is strategically being utilized in all key industries besides urban transformation.

INSIGHTS OF DIGITAL TWIN?

In essence, digital twin is a computer program or a software application. By utilizing real world data with the help of sensors, it creates simulations for predicting the performance of a product, process or system. The simulation so created is based on the current status as well as historical data and can predict future propositions also This computer program should have the capability of integrating IoT (industry 4.0), artificial intelligence and analytics software to enhance the output substantially.

With the advancement of machine learning and

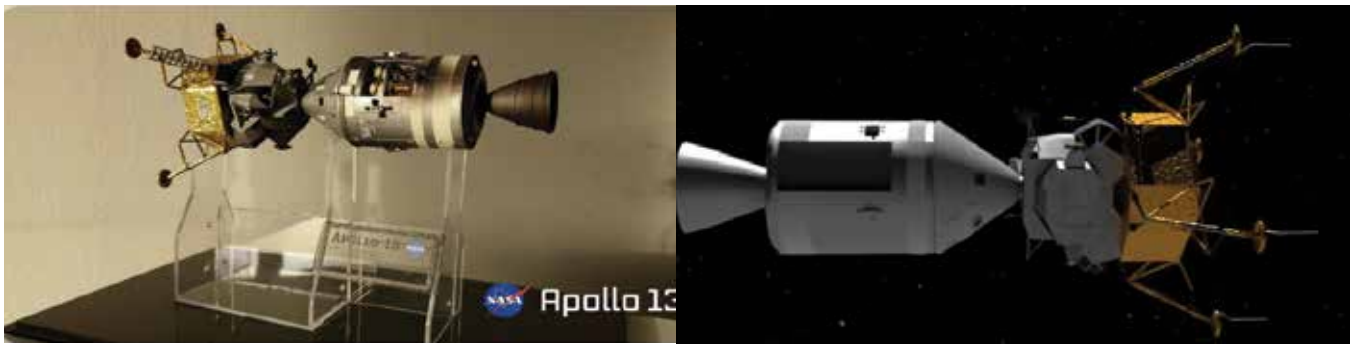


Fig. 3 : The physical replica of Apollo 13 prepared by NASA

factors such as big data, these virtual models have become essential in modern engineering to drive innovation and improve performance. The developers who create digital twins ensure that the virtual computer model receives feedback from sensors which gather data from the real world. A digital twin can therefore be as simple or as complex as required. The amount of data can vary depending upon the amount of precision required for virtual model to simulate the real-world situation.

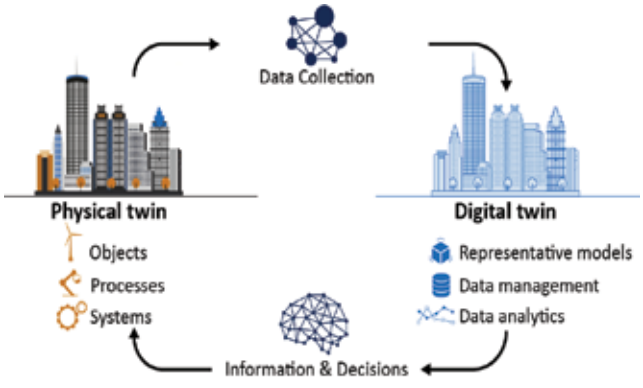


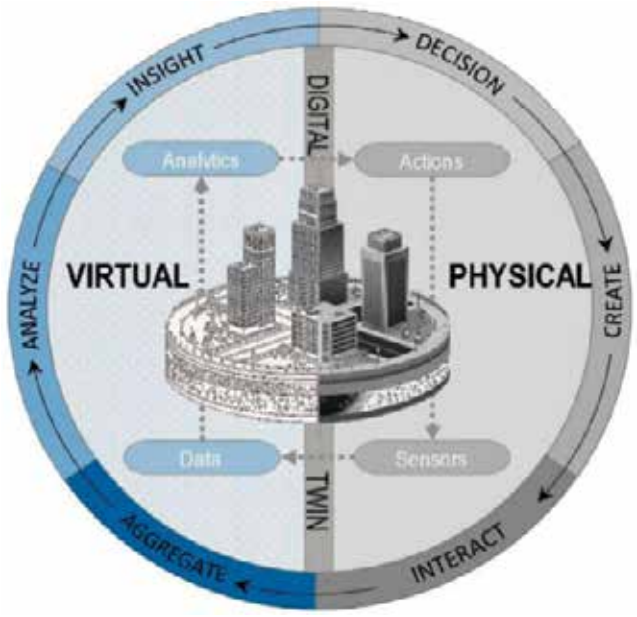
Fig. 4: Cyclic representation of digital twins. The use of IoT sensors allows for the transfer of real-world data to create virtual representations in the digital realm

BUILDING A DIGITAL TWIN & ITS SIGNIFICANCE IN URBAN PLANNING

Going for digital twin is like shifting from basics, from creating 2D maps and physical static models to more complex 3D virtual models. It is in fact, focusing more on data-dependent built environment by analyzing big data in which town and city planners, sustainable architects, project and structural engineers' dwell upon.

Urban planning requires various indicators such as population growth, land zoning, geographic mapping, analyzing parking space, source of water supply and distribution network, identifying transportation requirements of people and baggage, meeting of food supply demands, total electricity requirements and its growth over a significant period, health care and social services allocation etc. In short, it is a technical and political process which is focused on development and design of land use and built environment. Sustainability, climate change and carbon emissions are the new terms added to the above list of parameters.

Urban Planners tend to create simple prototypes based on their previous experience and expertise. But the above mentioned additions make the exercise more complex. Little bit trial here and more error there can create a scenario which may be difficult to conceive on paper and construct on ground due to numerous design changes and their subsequent visualization and impact on ground. Most of the carbon footprints in a metro city register through vehicles. This again affects Air Quality Index and health of citizens badly. One solution is to create clean transition towards electric mobility. But this requires a separate and huge infrastructure of charging stations in and around the city besides other essentialities. There are more and more solutions being provided by the various technologies which have emerged since the consciousness has crept in the human system about the adverse environmental impact created by the fossil fuels. But the requirements of these technologies are different and demanding as well. Returning to the Cycling is one solution but amid the fast moving vehicles, separate cycling track is required and that leaves a trail on already designed or conceived road network within the city. Likewise, there can crop up many



Digital Twin Concept

Fig. 5: Digital twin concept and how it helps the urban development

issues of urban mobility before conception, during conception and after conception. This is only one parameter requiring careful attention and interaction amongst the developers, planners, regulators and thought leaders. Likewise, there are number of issues like catering to the educational requirements, creation of replica of Nature in various land zones for better health of its citizens.

The integration of solutions of various and varied problems is not humanly possible and there, digital twin technology comes to the rescue of urban planners. Accurate visualization of city to be developed, amalgamation of various solutions in one visualization, improvement in the visualization from global practices etc. can help the planners to plan city as per the modern requirements to the best comfort & convenience of city dwellers. Thus, through various stages of developing and building digital twin of an upcoming city, planners can provide umpteen solutions with accuracy and acumen. Below is exhibited these stages in brief:

- **Defining objectives**

  A very careful first step. The objectives to be achieved are to be clearly comprehended before conceiving digital twin. Level of details, complexity and functionality of the digital twin can be decided only after clear objectives are set.

- **Choosing appropriate platform**

  Creation of successful digital twin depends on choice of suitable digital platform also. This platform should be able to support data ingestion, processing, storage and visualization of IoT devices inputs precisely. These platforms could be AWS IoT, Azure digital twin, IBM Watson IoT and Google Cloud IoT just to name a few. However, many more are emerging as this technology is gaining importance and momentum.

- **Designing virtual model**

  Very important step indeed! The, digital twin model is solely designed based for achieving objectives, data sources and formats of IoT devices. It is the backbone of comprehensive development for accurate visualization of built urban environment.

- **Implementing solution**

  Once model is ready, digital solution need be implemented on ground. It should therefore be communicated to various stakeholders involved in execution of project before hand to take their feedback for avoiding any confusion later.

- **Monitor and updation of digital twin**

  As digital twin evolves along with progress of physical infrastructure on ground, it should be monitored and updated regularly by the planners along with domain experts.

- **Secure and govern digital twin**

  As digital twin contain sensitive and confidential information, it should be protected from unauthorized access, modification or deletion. Encryption, authentication, authorization and auditing mechanisms are therefore required to secure data and communications related to specific project. Also, relevant laws and regulations regarding data protection, privacy, and ethics should be scrupulously followed to avail benefits of this technology.

ADVANTAGES

- **Improved Planning & Design**

  It provides insight to engineers and architects to simulate scenario and identify potential issues before being built at site. This enhances accuracy and innovativeness of design. Design thus becomes more inclusive.

- **Increased Collaboration & Communication**

  By providing real time view of project, it allows visualization of infrastructure remotely and simultaneous communication. This facilitates useful feedback from different stakeholders for improvement of services etc.

- **Improved Operational Efficiency**

  By real time monitoring and data analysis of the infrastructure after its completion.

- **Enhanced Sustainability**

  Optimization of energy consumption and thereby reducing building's carbon footprint ensures sustainability of purpose as well as long term sustainability.

- **Cost Reduction**

  Avoid delays and costly rework by identifying and resolving issues before construction begins thus major cost reduction and timely completion of project is possible.

  Besides above, there could be many more advantages like preparedness for disaster management etc.

FUTURE TRANSITION OF DIGITAL TWIN TECHNOLOGY

Urban Metaverse is poised to be the future extension of Digital twin technology. Though Metaverse is in primary stage of development now but by 2030, this form of digital transformation will take over urban digital twin platforms and solutions. This is particularly so because future urban environments are going to be much more complex and will therefore be not easy to design, explore, maintain and engage with. The technology transition is thus going to sweep the globe with a break-neck speed during next decade. A little light on urban metaverse will be very interesting. It is a revolutionary technology in urban planning. By creating immersive digital environments, it can create wonderful visualization of complex city projects and infrastructure.

Urban planning of modern cities involves designing land usage, creating infrastructure for well-connected and economic transportation, digital communication, and power and water distribution networks etc., while making continuous improvements as well as adjustments. Therefore, by creating digital replicas of real urban eco system to facilitate virtual collaboration for designing and evaluating city development scenarios to ensure effectiveness, sustainability, and durability urban metaverse can enhance the concept of digital twin further. Thus, digital transformation has endless possibilities and we are only at the beginning. There is much, much and much more to be unveiled.

Fig. 6: Digital scripts of complex floating city and building structures which generate their own renewable

CONCLUSION

It is no longer a matter of surprise that future belongs to Digital Twin technology, which is going to build the future urban eco-system by systematically planning the complex urban spaces and implementing the virtual built environment on

ground. Digitalization, especially digital twin being precise virtual copies of systems, is revolutionizing every field of human activity with ease and finesse. With the advancement of information technologies, especially the emergence of New Information Technologies such as Internet of things, cloud computing, big data analytics, and artificial intelligence, digitalization process is greatly accelerating. Through the convergence of the physical and virtual worlds, digitalization is poised to become one of the main drivers of innovation in urban planning and development.

Thus, digital twin technology will help in building a better world despite complex and dynamic urban environment. This will prove to be game changer for creating zero emission and seamless infrastructure with clean water, affordable energy, right facilities and services across the country. In summary, digital twins enhance our ability to understand, learn, and reason from changes in physical twins and their environment. It would help the planners, developers and facility builder to visualize processes, monitor the performance and eliminate problems before they occur. This helps them from being reactive to predictive which is the bottom line of this technology.

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SMART CITIES MISSION : ISSUES AND PROSPECTS

R. Srinivas*

Abstract

The Smart City Mission was launched by Prime Minister in 2015. Mission provides opportunity to cities and towns to adopt area based strategies and make the use of ICT for effective and transparent delivery of urban services. The paper attempts to assess the challenges in terms of service delivery and highlights the emerging issues. It also discusses the vast opportunities for Indian cities to facilitate the role of technology in urban planning and governance.

INTRODUCTION

Presently half of the world's population lives in urban settlements. As per United Nations forecastl, the proportion of human population is expected to grow to nearly 60% by 2030 and 70% by 2050 with almost 6.3 billion urban population out of the total population of 9.55 billion.

The urbanization and growth of our cities and towns is irreversible and is gaining momentum. As per Census, 2011 there are 7933 cities and towns and by 2051, half the population of India would reside in urban settlements. It is estimated that the number of metropolitan (million plus) cities would be more than 100 and total number of the urban centers would be more than 10000. The contribution of urban settlements to the GDP may be around 75%-80% and they would play a key role in overall national development.

They have been contributing over 50% of the country's GDP and always been the generators of economic momentum. In the 2000's, it was realized that cities and towns require massive investments for infrastructure upgradation/renewal and under JNNURM, the flagship programme of Ministry of Urban Development (2006-2014) , it was for the first time in the history of urban development when ₹1 Lakh Crore was envisaged for creating and strengthening the urban infrastructure. The High-Powered Expert Committee (HPEC) Report, 2011 also made an estimate for the investment for urban infrastructure over the 20-year period to the tune of ₹39.2 Lakh Crore at 2009-10 prices.

**Former Town and Country Planner, Town and Country Planning Organization, Ministry of Housing and Urban Affairs*

There has been growing realization that cities and towns should be treated as investment and revenue gateways for the other development programs. Although the urban sector contributes more than 90% of total government revenue, yet only a fraction of this is able to be ploughed back as in the various Five-Year Plans. The allocation for urban development was under 5% with 4.6% to the total allocations made during 12th Five Year Plan (2012-2017) was the highest compare to the previous Five-Year Plans.

The post 2014 scenario, the budget during 2014-2023 has been significantly higher than the preceding 10 years in the sector. Further, estimated investment in the urban schemes under Ministry of Housing and Urban Affairs has increased manifold from ₹1,78,053 crore during 2004-14 to ₹18,07,101 crore during 2014-23. This includes investment in Central Government urban schemes of Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart Cities Mission, Pradhan Mantri Awas Yojana - Urban PMAY-U), Swachh Bharat Mission (Urban) and Urban Transport.

CHALLENGES FOR ENSURING ACCESS TO URBAN INFRASTRUCTURE

In this typical development scenario, the urban population in the country has to continuously struggle with theaccess to urbaninfrastructure such as water supply, drainage, sewerage, scientific solid waste disposal, housing and urban transport. Further, cities also have to face the problem of inequities in distribution of infrastructure among different income groups of population.

Infrastructure inadequacies and inequitable distribution are accompanied by the absence of efficient and effective management which has led to ineffective linkages and losses and the deficiencies in services in urban areas. These are largely absorbed by the low income and poor sections of the population.

Indian cities provides ample opportunity for planned development and the challenges are manifold. These challenges are discussed in the following sections.

- **Housing Shortage and Slums**

  Over the last few decades, due to massive urbanization, increasing income levels and changing demographics, there has been increasing pressure of housing, transportation, land and other urban services. At the national level, it has been estimated that the total urban housing shortage was 18.78 million units in the 12th year plan (The Technical Group on Urban Housing, 2011). With these 18.78 million units, the housing shortage amongst the Economically Weaker Section (EWS) and the Lower Income Group (LIG) is extraordinarily high with a 96% share of the total shortage.

  Further, as per Cushman & Wakefield Research[2], India is likely to witness urban housing demand of nearly 13 million units by the end of 2018. Of this, about 19% demand (2.47 million units) would arise from the top eight cities namely- Ahmedabad, Bengaluru, Chennai, Delhi-NCR, Hyderabad, Kolkata, Mumbai, and Pune in India, with LIG (0.85 mn units) and MIG (0.88 mn units) segments likely to account for the major chunk (about 80%) of the total demand.

  Moreover, as per Census 2011, 52.4 million people lived in slums in 1743 towns which constitute 23.5% of the population of these towns. There is acute shortage of housing in urban areas and much of the available accommodation is qualitatively of sub-standard variety. This problem has tended to worsen over the years due to rapid increase in population, fast rate of urbanisation and proportionately inadequate addition to the housing stocks. Millions of people pay excessive rent which is beyond their means thereby making the housing especially in million plus cities an unaffordable proposition.

  The major constraints in developing housing in India are:

  1. With growing population and expanding cities, there is paucity of land that can be developed for creating new housing stock.
  2. Private sector's participation in the creation of low-cost housing stock in India has been limited due to the reasons such as limited margins, longer time frames for such projects, rigid institutional and regulatory frameworks etc.
  3. Financial exclusion of the vulnerable and weaker sections from the formal system limits their prospects of buying or building their own homes.
  4. High construction cost of the project is also one of the major constraints.
  5. Rigid and tedious regulatory framework for approval of developing new housing stock.

- **Water supply, Drainage and Sanitation**

  In India, most of the cities have certain problems of adequate water supply. The latest status states that 97.7% of India's urban areas had access to water in 2020. More than 80% of urban households have water on-site, and more than 90% of the urban population has access to drinking water. However, there are still significant water supply inequalities between cities. According to a 2019 report from NITI Aayog, almost 600 million people in India are water deprived. Metropolitan cities like Delhi, Bengaluru, and Hyderabad are also close to running out of groundwater.

  Based on the study titled "Reassessment of Water Availability in India using Space Inputs, 2019" conducted by Central Water Commission, the average annual per capita water availability for year 2021 and 2031 has been assessed as 1486 cubic meter and 1367 cubic meter respectively. Annual per-capita water availability of less than 1700 cubic meter is considered as water stressed condition whereas annual per-capita water availability below 1000 cubic meters is considered as a water scarcity condition. Many small towns have no piped water supply at all and are dependent on the underground water that is fast depleting and contaminated.

  According to the World Health Organization (WHO), 83.36% of the Indian population has access to basic sanitation in 2020, with 16.63%

utilizing open defecation and unimproved sanitation. However, the situation is significantly better in urban areas, with 98.58% of the population having access to improved sanitation facilities and just 1.41% using open defecation and unimproved sanitation. It is important to note that while open defecation and poor sanitation have declined in India, there is still a significant population that prefers open defecation, particularly in urban areas. India continues to have the largest urban population that practices open defecation worldwide, with 4.76 million people still practicing it. Despite the government's efforts to improve sanitation through schemes like Swachh Bharat Abhiyan, much work remains to be done to improve the existing conditions of sanitation in urban India and to ensure that all residents have access to adequate sanitation services.

Drainage needs much improvement in urban areas and large pools of stagnant water can be seen in city even in summer months. Removing garbage, cleaning drains and unclogging sewers are the main task of urban local bodies. There is both fund constraints and lack of capacity being faced by the local bodies to tackle the basic sanitation needs of the cities. The spread of slums in congested urban areas and lack of civic sense among the settlers in these slums further aggravate the menace of filth and diseases.

- **Solid Waste Management**

Solid waste management is one among the basic essential services provided by urban local bodies in the country to keep urban centres clean. However, it is among the most poorly rendered services in the basket—the systems applied are unscientific, outdated and inefficient; and population coverage is low. Waste is littered all over leading to insanitary living conditions. With rapid urbanization, the situation is becoming critical. Urbanization directly contributes to waste generation, and unscientific waste handling causes health hazards and urban environment degradation. Solid Waste Management which is already a mammoth task in India is going to be more complicated with the increase in urbanization, changing lifestyles and increase in consumerism.

About 1,88,550 MT of Municipal Solid Waste is generated daily in the country. The 53 cities in India with million plus population together generate 86,000 MT (31.5 million tons per year) of MSW at a per capita waste generation rate of 500 grams/day. Cities with 100,000 plus population contribute 72.5 % of the waste generated in the country as compared to other 3955 urban centres that produce only 17.5 % of the total waste[4].

Indian cities are still struggling to achieve the collection of all MSW generated. Metros and other big cities in India collect between 70% - 90% of MSW. Smaller cities and towns collect less than 50%. It is also estimated that about 2% of the uncollected wastes are burnt openly on the streets. About 10% of the collected MSW is openly burnt or is caught in landfill fires. Such open burning of MSW and landfill fires together releases 22,000 tons of pollutants into the lower atmosphere thereby degrading the natural environment.

Financial constraints, institutional weaknesses, improper choice of technology and public apathy towards Municipal Solid Waste (MSW) have made this situation worse. The current practices of the uncontrolled dumping of waste on the outskirts of towns/cities have created a serious environmental and public health problem.

- **Transportation and Traffic**

Currently, public transport in major metro cities satisfies a considerable portion of the commuting demand (50-60%). Nevertheless, flawed private vehicle policies have led to detrimental consequences, such as increased congestion and travel times, as evident from the high congestion levels in cities like Bengaluru, Mumbai, Pune, and New Delhi – they have all secured positions within the top 10 most congested cities across the globe. The congestion levels recorded in these cities paint a concerning picture of the challenges they face.

However, the share of public transport may be expected to decrease as there is a likely

decrease in the speed flow of public transport from 26-17 km/h to 8-6 km/h during the same period 5. In 2007, a study commissioned for the Ministry of Housing and Urban Affairs, Government of India, found that the average journey speed in Delhi was around 16 km/h and only slightly higher in Mumbai[6].

Absence of planned and adequate arrangements for traffic and transport is another problem in small and medium towns in India. Majority of people use para transit while a few use rail as transit system. The increasing number of two wheelers and cars make the traffic problem worst and cause air pollution as well. Moreover, the number of buses plying in the metropolitan cities is inadequate and commuters have to spend long hours to travel.

- **Power Shortage**

  In India, energy is not distributed equally between urban and rural areas. Urban areas use a lot of non-renewable energy, whereas rural areas use both renewable and non-renewable forms like hydro-electricity.

  Despite the impressive increase in the installed capacity, the electric power supply continues to remain short of demand. The demand projections made in the 16th electric power survey conducted by Central Electricity Authority indicated that over 1 lakh MW additional generation capacity is needed in coming years to bridge the gap. However, it is a matter of great concern that in spite of the growing demand for power, the annual per capita consumption of India at about 350 kWH is among the lowest in the world.

  India's energy requirement is increasing sharply because of rapid industrialisation, mechanisation, urbanisation, commercialisation, population growth, and changing lifestyle of the people. The excessive demand has put a strain on the power production facilities; especially as India's power production is derived primarily from conventional sources such as thermal generation or hydroelectric. Power supply has remained insufficient in a majority of the urban centres in India. The shortages are often attributed to inadequate investments in distribution and transmission.

  Aggregate Technical & Commercial (AT&C) losses which include theft, non-billing, incorrect billing, inefficiency in collection and transmission and distribution losses exceeded 20% for the country as a whole in 2024 which has considerable brought down from 42% in 2005 largely due to privatization of power distribution.

PLANNING & MANAGEMENT OF URBAN AREAS

To ensure efficient management of our urban areas, not only existing deficit in infrastructure and services needs to be addressed but provision has to be made for catering to future needs as well. The financing requirements for improving present cities as well as orderly urban growth and expansions are indeed enormous.

There is hardly any need to emphasize that the urban sector in the Indian context is going to be confronted with various challenge in order to ensure access to basic urban infrastructure but also quality of life. Thus, seriousattempts will have to be made on the following issues like:

- Efficiency of the urban settlements in the country largely depends on how well they are planned.
- How well they are developed economically and how efficiently they are managed.
- Urban development planning practice has in the past, besides being unduly time consuming been largely confined to the detailing of land use aspects. How this has to be made dynamic in view of emerging paradigm and also efforts for reducing the timelines for preparing the Master/ Development Plans
- Proper implementation of Master Plans / Development Plans is a critical aspect in the regulated development of cities and towns.
- Although a number of Development Plans / Master Plans for important towns and cities have been prepared so far(about 1600), their implementation has not been satisfactory due to a variety of reasons which in turn have resulted in mushrooming of slums and squatters, unauthorized and haphazard development and above all environmental degradation and transportation problems.
- Addressing infrastructure deficiencies in cities and towns is a daunting task. Cities are expected

to continue to grow in the foreseeable future. Therefore, the deficiencies too will become ever more pressing.

- Growth challenges of our cities are far ahead of the ability of the traditional financing models and planning and execution of service delivery.

TECHNOLOGICAL INTERVENTIONS- QUEST FOR SMART URBANIZATION

In order the cope up with the challenges of managing the urban infrastructure especially in view of growing urbanization and with the future urbanization scenario. Hence, it becomes essential that with the advent of numerous technological innovations, the challenges and opportunities for the country in bringing 'intelligence or smartness to its infrastructure – the physical networks that deliver services as transport, telecommunications, water and sanitation, energy that how over the next 50 years, we can really apply the latest technologies to the design and implement intelligent infrastructure for robust, sustainable and safe urban infrastructure.

An important attribute of an intelligent system is that it uses the resources as effectively as possible to deliver maximum return for minimal investment of effort. For example, the scenarios explore how the intelligent design of urban transport (TOD) for reduced travel could improve the performance of the infrastructure. Similarly, sensors and other technologies may be built into infrastructure to deliver intelligence about infrastructure performance. How the Remote Sensing and GIS can be effectively used to reduce the timelines of preparing Master/Development Plan with a view that all urban local bodies (4900) should have the availability of same within next 5 years by 2027

The application of information and communications technologies (ICT) makes the infrastructure intelligent. In planned development of cities and towns, environment investment in technology primarily focuses on minimizing adverse impacts on natural and built environment. Good environmental practice is to be followed with the objectives of sustainable buildings, distributed power generation and new urban planning paradigm to create compact and sustainable cities which is not only cost effective but also encourages increased dependency of public transport. Cities and towns are supposed to be far more environmentally friendly as they use sustainable materials for building facilities and reduce energy consumption.

The use of technology through a network of sensors, cameras, wireless devices, data centres form the key infrastructure, which allows urban local bodies to provide essential services in a faster and more efficient manner.

THE OPTIONS AND EMERGING PRACTICES

Cities and towns if they want to remain competitive in view of globalization will have to adopt the innovations and the planners and administrators will have to be proactive to adopt innovations. Some of the cities which were covered under JNNURM like Chennai, Coimbatore, Mumbai, Ahmedabad, Surat and Pune had taken number of steps to adopt aforementioned innovations. Some of green field developments in Magarpatta, Lavasa, Greater NOIDA have also demonstrated that planned development with latest practices being adopted like negotiated land acquisition, use of solar energy and waste in generating power, scientific disposal of solid waste and decentralised waste water treatment are the steps towards smartness in urban planning. The emerging issues in urban development are given as under:

- Public transport: use of clean and green energy to be encouraged.
- Competitive cities have the IT infrastructure needed to link high-value knowledge businesses, but there has to be integration of IT supporting transport systems.
- Rural areas to be well integrated effectively acting as food and bio-fuel sources for cities.
- Water supply, sewerage, drainage and solid waste management to be made viable infrastructure by using innovative techniques like SCADA which can ensure reduced transmission and distribution losses.
- Unlocking the value of land by assembling the vacant land and put for resource generating uses.
- Resource use to be part fundamental part of the tax system.

For the urban sector the focus has to be :

- 24x7 water supply along with steps for waste water recycling and reuse, rainwater harvesting.

- Zero Waste concept - The waste being generated to be recycled and to the possible extent minimum waste to be dumped. Possibilities of exploring gas generation from waste and use of recycled waste in road construction.
- Transit oriented development - Intensification along the MRTS/BRTS corridors in view of no scope for lateral growth.
- Compact city development - Reduction in use of personal mode and reduction in trip generation and encourage pedestrian movement.
- Green Cities - Environment sustainable by adopting innovations using alternative technologies with the use of solar energy and other renewable sources. Use of Cleaner technologies and low-emission energy to be encouraged.
- E governance - ULB using E-Governance mode thereby streamlining the plan sanction process and other clearances to be given while undertaking the construction activity.

SMART CITY MISSION

Realising the significance of the emerging issues the Prime Minister launched the Smart City Mission on 25th July, 2015. In his address he stated that a city which is two steps ahead of its citizen's needs is a smartcity. He stressed that as the world looks to India, we have to work towards reaching the world standard. We cannot feel disheartened that the world has progressed and we missed the bus8. The Cabinet in April, 2015 had approved Rs. 1 lakh crore investment on Smart Cities Mission and the Atal Mission for Rejuvenation and Urban Transformation of 500 cities (AMRUT) with outlays of ₹ 48,000 crore and ₹ 50,000 crore, respectively.

- **Objectives of Smart cities Mission**

  As per the Mission guidelines, a Smart City has basic infrastructure that uses 'smart' solutions to make infrastructure and services better, and relies on area based development. The objective is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on sustainable and inclusive development and the idea is to look at compact areas, create a replicable model which will act like a light house to other cities.

- **Salient Features**

  The key features of a Smart City are its Competitiveness, Sustainability and Quality of life.

  Competitiveness refers to a city's ability to create employment opportunities, attract investment and people. The ease of being able to do business and the quality of life it offers determines its competitiveness.

  Sustainability includes social, environmental and financial sustainability

  Quality of Life includes safety and security, inclusiveness, entertainment, ease of seeking and obtaining public services, efficient and economic healthcare, quality education and opportunities for participation in governance.

  The Mission Guidelines[9] objectives have to be achieved through the following efforts:

  i. Promoting mixed land use in area-based developments — planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The States will enable some flexibility in land use and building bye-laws to adapt to change;

  ii. Housing and inclusiveness — expand housing opportunities for all;

  iii. Creating walkable localities — reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;

  iv. Preserving and developing open spaces — parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;

  v. Promoting a variety of transport options — Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;

vi. Making governance citizen-friendly and cost effective — increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices; form e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

vii. Giving an identity to the city — based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc;

viii. Applying Smart Solutions to infrastructure and services in area-based development in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

- **City Challenge Competition (Stage I and Stage II Competition)**

  For the first time in the history of implementing urban development programmes, an element of competitiveness has been introduced. The selection process for smart cities has been envisaged in two stages, Stage I is essentially intra-state competition wherein each state shall shortlist certain number of smart city aspirants based on the criteria given in the Guidelines (Form-2). The Stage II will be an all-India competition and cities will prepare smart city proposals (SCP) for further evaluation for receiving central assistance. Each city has to develop its own idea of a smart city, vision, and submit a Smart City Proposal (SCP) during the pan-India competition. The Stage I competition was completed on 31st July, 2015.

- **Identification of Smart Cities (based on Stage I competition)**

  On 27.8.2015 Minister of Urban Development announced a list of 98 cities and towns selected for development as smart cities. These cities and towns were nominated by respective States and Union Territories at the end of first stage of 'City Challenge' competition in which all the urban local bodies in each State and UT were evaluated based on their financial and institutional capacities and past track record.[10]

  The details of cities are given as under:

  -24 cities are capital cities;

  -24 are business and industrial centres;

  -18 are of cultural and tourism importance;

  -5 are port cities and three are educational and healthcare hubs.

  In terms of population:

  - 8 have population up to one lakh.
  - 35 have population between one and five lakh;
  - 21 cities are in the population range of five to ten lakh;
  - 25 have population of above 10 lakh and below 25 lakh; 5 in the range of 25 to 50 lakh and
  - Four viz., Chennai, Greater Hyderabad, Ahmedabad and Greater Mumbai have population above 50 lakh.

The cities selected under Smart City Mission have a population of about 13 crore account for over 35% of the country's urban population. The 65 small and medium towns and cities making to the list of smart city would lay a robust foundation for better urban planning and management.

- **Smart City Proposal (SCP)**

  Under the Smart Cities Mission, all the selected cities will have to prepare Smart City Proposals (SCPS) and these will be evaluated in the second stage of competition based on a broad set of criteria to pick up the top scoring 20 cities for funding during 2015-16. Funds shall be released to these 20 cities by the end of this year. The other cities will be requested to improve upon the identified deficiencies before participating in the next two rounds of competition. Those cities to be selected in the second stage of competition would be provided with central assistance of Rs.200 Crore in the first year followed by Rs.100 Crore each year during the next three years.

- **Area based approach**

It will be implemented through 'area based' approach consisting of retrofitting, redevelopment, pan-city initiatives and development of new cities. Under retrofitting, deficiencies in an identified area will be addressed through necessary interventions by Developing an existing built area greater than 500 acres so as to achieve the objective of smart cities mission to make it more efficient and livable for example, Local Area Development (Ahmedabad). The redevelopment shall cover an existing area of more than 50 acres and enable co-creation of enhanced infrastructure, mixed land use and increased density for example, Bhendi Bazar, Mumbai while under green field, develop a previously vacant area of more than 250 acres using innovative planning, plan financing and plan implementation tools with provision for affordable housing, especially for the poor for example, New Town, Kolkata.

- **Investment Requirements**

Ministry of Housing and Urban Affairs had committed Rs. 20,000 crore per annum for smart cities, however, the investment requirements of a Smart city are to the tune of Rs. 35000 crore per annum on the basis of (HPEC) estimates of Rs. 43,386 per capita cost over 20 years at 2009-10 prices.)11. This does not include the cost for housing, healthcare, education, entertainment, economic infrastructure, ICT applications and capacity building.

PROGRESS OF SMART CITIES MISSION

1. **Madurai:** Completed 100% of projects.
2. **56 Cities:** Completed over 80% of work.
3. **Lagging behind:** 14 cities at 50% progress or below.
4. **Lagging cities primarily from the northeast, Union Territories, and hilly areas.** Examples include Gangtok, Atal Nagar, Shillong, Silvassa, Itanagar, Puducherry, Saharanpur, and Port Blair with completion percentages ranging from 16% to 39%.

- **Achievements of Smart Cities Mission**

- **Digital Transformation:** Implementation of smart technologies for efficient governance and service delivery, such as Integrated Command and Control Centres (ICCCs) in all 100 Smart Cities.
- **Alignment with Sustainable Development Goals (SDGs):** Over 70% of projects align with UN SDGs, particularly SDG11 (inclusive, safe, resilient, and sustainable cities).
- **Infrastructure Development:** Improvement of urban mobility through metro lines, BRTS, and pedestrian-friendly pathways.

- **Smart Cities Mission Success Stories**

- **Ahmedabad:** Sensor-based water network monitoring increased supply by 50 MLD.
- **Indore:** Gravity-based network prevented 205 MLD of untreated sewage from entering water bodies.
- **Visakhapatnam:** Mudasarlova Reservoir Floating Solar Plant generated 3,613 MWh annually, preventing over 3,000 tonnes of CO_2 emissions.

PARLIAMENTARY STANDING COMMITTEE RECOMMENDATIONS ON EVALUATION OF SMART CITIES MISSION[13]

The Parliamentary Standing Committee recommendation on Smart Cities Mission (SCM) is that the Mission should be extended to a second phase with a focus on second-tier cities to decongest state capitals, and special purpose vehicles (SPVs) created to run the mission be continued. The Committee observed that cities such as Lakshadweep, Daman and Diu, Puducherry, and Port Blair have been released below 50% of pledged central funds.

The matching contribution by the state government/ ULBs, only 28 cities have received 100% of their share of funds from states/ULBs. However, funds released by states/ULBs have been below 60% in 14 cities.

They also recommended that Ministry of Housing and Urban Affairs to ensure that the impact of the mission is long lasting even as it flagged several shortcomings such as the failure of the participating cities to raise funds through PPP and other sources, an inter-city disparity in the implementation of SCM projects, lack of defined governance structure and monitoring capacity of the SPVs.

The infrastructure and the digital assets created under SCM should be maintained and privacy safeguards be put in place, the Centre should assist the cities in formulating masterplans for greenfield development, engage elected representatives in planning and decision-making.

The Committee observed Madurai was the only among the 100 smart cities to complete 100% of the projects by December 2023, the previously proposed deadline for the completion of the projects. 56 cities completed more than 80% of the work in the same time frame. However, the progress of work was 50% or below 50% in 14 cities by then. Gangtok, Atal Nagar, Shillong, Silvassa, Itanagar, Puducherry, Saharanpur, and Port Blair completed only 16%, 23%, 24%, 28%, 31%, 32%, 35% and 39% of projects respectively.

Those lagging were cities from the northeast, Union Territories, and the hilly areas.The Committee further observed that a separate plan be chalked out to ensure that smaller cities like those in the northeast can reap the benefit of the scheme noting that even the increase in central funding to 90% from the original 50% did not yield any result.

The committee also observed that only 6% of projects for the flagship SCM projects across 100 cities could be funded through public-private partnerships (PPPs) as opposed to the recommended 21% and almost 50 cities could not generate any funding via this method. It has desired that Ministry of Housing and Urban Affairs to analyse why the drive failed and introduce remedial measures noting that government funding alone cannot meet the cost of increased infrastructure in cities. There was a lack of a robust mechanism to ensure coordination and smooth and harmonized monitoring for convergence and to ward off duplication and wastage of resources.

- **Need for IT strategy, privacy safeguards**

  The committee also highlighted that given the introduction of integrated command and control centres (ICCC) as part of Smart Cities, there is a need for a comprehensive framework and operation and maintenance strategies to ensure increased lifetime utility, value of infrastructure/ assets and their timely upgradation.

  It has been recommended that assessment should be done about the number of ICCC platform required in various cities of a state and thereafter steps should be taken to create a state-level ICCC for connecting and putting together all the ICCCs in the state to create a common e-governance platform.

  It has been noted by the Committee that various applications of these ICCCs like CCTV surveillance systems, early warning and disaster response systems and other functions will generate and use large volumes of data from these varied digital sources. It is strongly recommend that a robust system should be put in place to protect digital platforms from cyberattack and to ensure that sensitive public and private data is adequately protected and safeguarded.

- **Involvement of elected representatives, fixed tenure of CEOs**

  The Committee noted that the frequent transfer of CEOs and lack of clear guidelines and directions for CEOs with fixed tenure by the ministry is one of the reasons for projects facing delays. The committee recommended CEOs with a minimum fixed tenure along with representation from the city administration, local self-government, experts in urban development and concerned stakeholders which will ensure clear accountability, and transparency in working of the Mission.

  Further, the committee noted that the state-level advisory forum meetings which include MP, MLA, Mayor, District Collector, CEOs of the smart cities are not held regularly. On average, one to eight meetings have taken place in the first five years of the Mission and it was felt by the committee that most of the Smart Cities failed to leverage the expertise and grassroot connection of Members of Parliament and other representatives/experts by not convening the meetings of Smart City Advisory Forum (SCAF) regularly.

CONCLUSION

The Smart City Mission provides an opportunity to learn from past experiences and improve upon the constraints in urban governance and to enhance quality of life for all the citizens. The smart cities mission has created a chance to catalyse progress in three key areas:

- Area based strategies to overcome problems at the local level
- Efficient and transparent urban governance

- Monitoring of the service delivery through ICT Applications

As per World Bank Report[12] on PPP, many Indian cities lack effective coordination among different sectors of government, and instead focus too often on public-private partnerships without first focusing on inter- departmental issues. This can result in infructuous expenditure that fails to create sustained impact. Hon'ble Prime Minister has emphasized that a key component of smart cities is improving the way city government's function. There is a need to promote coordination across departments and reduce delays in decision-making.

Smart cities should also be evaluated based on their ability to provide equitable economic opportunity and access to basic infrastructure for all residents. Like effective governance, widespread access to basic infrastructure is a prerequisite for effective technology-driven urban improvements. When pursuing increased competitiveness and economic growth, smart cities cannot lose sight of the challenges faced by India's urban poor, example, increasing school attendance rates, improving public health, child mortality and vector borne diseases.

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URBAN CHALLENGES AND INNOVATIONS FOR VIKSIT BHARAT

A.K. JAIN*

Abstract

India is moving to become a developed country by 2047, It would be one of the World's largest economy and urbanisation shall be its backbone. It poses huge challenges for urban planning and development ranging from climate and disaster resilience, adaptation and mitigation, low carbon fuels and zero emission industries, equitousand inclusive development, jobs, renewables and energy efficiency, circularity in construction and resources management. These call for a radical transition in planning for engagement with a vision of viksit India @ 2047 competing with global south cities like Singapore, Dubai and Bangkok.

INTRODUCTION

The 21.8 km long Mumbai Trans Harbour Link (MTHL) or the Atal Setu, built at a cost of Rs. 1,250 crore and inaugurated by Prime Minister Shri Narendra Modi on 12th January 2024, will help the development of a third Mumbai (Figs. 1 & 2). The 16.5 km part of the bridge is over the sea, which is the longest in India. It symbolises the resolve of the nation towards visionary and ambitious urban development. It will scale up Mumbai's economy from existing $140 billion to $250 billion and enable the development of 323 sq.km for 3rd Mumbai in the Mumbai Metropolitan Region (MMR).

The project demonstrates the innovative ways to tackle the challenges of environmental sustainability, financing, departmentalisation and gaps between planning and implementation. India is moving towards a developed economy by the year 2047 and urbanisation will be its backbone, providing 75% of GDP and jobs. The cities being the crucible of ideas, investments and innovations, it is critical to evolve a new vision towards resilient, accelerated, innovative, responsible, sustainable, and equitable (RAISE) urban habitats.

THE URBAN CHALLENGES

In 2047 India will have a population of 1,640 million, i.e. one-sixth of world's population surpassing China. Its urban population is projected to increase from 377 million (2011) to 820 million in 2047. It will have the world's largest workforce and will be the world's third largest economyof $36 trillion. With its rapid pace of urbanisation and economic growth, it is projected that 75% of GDP and new jobs will be created in the cities. This poses huge challenges for urban planning and infrastructure development.

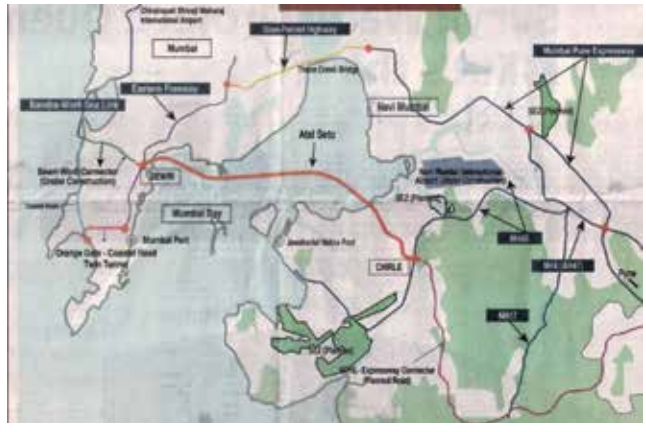

Fig. 1: Plan of Mumbai Trans-Harbour Link (Atal Setu) inaugurated by the Prime Minister Narendra Modi on 12th January 2024

Source: MMRDA, 2024

Fig. 2: Mumbai Trans-Harbour Link (Atal Setu)

**Former Commissioner (Plg.), DDA, New Delhi*

According to the Report of NITI Aayog (2022) on reforms on Urban Planning Capacity in India, a city Master Plan is essential for socio-economic development, better liveability, inclusion, citizen engagement, environment sustainability and climate change related aspects. According to the report, India's cities occupy 3% of area while contributing a massive 60% to the country's GDP. However, in Indian cities more than half of its housing and buildings are unsafe, unauthorised, and dilapidated. According to the Census 2011, about 17.4 percent of India's urban population, i.e. 65 million are living in the slums. The Master Plans have been prepared only for 2,000 odd cities against 7936 cities and towns in India. The plans often fall short of the issues of sustainability, circularity, climate change and resilience. The planning process is usually slow with shortage of investments. There is a serious lack of coordination in implementation. It does nor synchronise with the India's roadmap towards achieving net zero emissions by 2070, 50% of energy from the renewables and reducing emissions by 45% by 2030. This is witnessed by higher level of pollution, slums and unplanned settlements, perennial traffic jams, lack of spaces for pedestrians, cyclists and greenery. The conventional plan follows the colonial 20 year model and does not take into stride the urgency, new technologies, innovative ways of land assembly, financial investments, partnerships and participatory approaches. As a result, there are stark asymmetries in the vision and the reality. This calls for radical changes in the urban processes and learning from the success stories like Mumbai Trans Harbour Link, India's Urban Missions, PM Gati Shakti Master Plan, National Monetisation Pipeline and new technologies.

INDIA'S URBAN AND HOUSING MISSIONS

The Government of India in 2014-15 launched several urban missions, viz. Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Pradhan Mantri Awas Yojana (PMAY), Historic City Development and Augmentation Yojana (HRIDAY) and Swachh Bharat Mission (SBM). The Atal Mission on Rejuvenation and Urban Transformation (AMRUT) has covered more than 5,800 projects related to water, green spaces and mobility. The Swachh Bharat Mission (Urban) (SBMU) tackles urban sanitation and waste management, having provided a record 9 million toilets. The plans under these missions are based on digital planning via computing processes with net zero energy, water and waste together with circular systems.

The Smart Cities Mission envisages development of 100 smart cities which are infused with intelligence, integrity and inclusion with state of art infrastructure services, transport and housing for all. These missions aims to develop sustainable cities with carbon neutral buildings, green energy and transport, water conservation, wastewater and solid waste recycling, sanitation, sewerage and STPs for protection of water bodies, rivers, and drains. Swales, sponge/porous paving, bio-drainage, storm surge gates in river, drains and canals and zero run off drainage save human settlements from floods. Rooftop solar panels, insulated green roof, ventilation, shaded spaces and greenery reduce city's heat build-up. District cooling system and Earth Air Tunnel with cool air in subterranean clay pipes, save on air-conditioning and help in reducing the urban footprints, formation of heat islands and pollution.

The PMAY (U) till September 2023 has been able to build and deliver more than 10.3 million houses, while 12.03 million have been sanctioned (Table 1).

A major component of the PMAY (U) is slum rehabilitation and redevelopment by adopting the following measures:

- Community led mapping and enumeration of slum households
- Establishing service level benchmarks for assessment of their upgradation needs
- Forging partnership among the communities for their participation in the decision making and urban planning
- Building of rental housings and grant of land rights
- Improving urban basic services, public transport, and social facilities
- Facilitating the informal families access to finances and institutional home loans.

For coordination of various urban issues, the Integrated Command and Control Centre (ICCC) is one of the key projects under the Smart Cities

Table 1: Progress of Pradhan Mantri Awas Yojana (Urban)

Sl. N.	Particular	CLSS	% of CLSS to Achieve-ment	ISSR	% of ISSR to Achieve-ment	AHP	% of AHP to Achieve-ment	BLC	% of BLC to Achie-vement	Achievement under PMAY (U)
1	City/Towns Covered (Nos.)	6958	91.9	162	2.1	981	13	4332	57.2	7570
2	Project(s) Approved (Nos.)			315	1.1	2245	8.0	25405	90.9	27965
3	Investment (Central, State & Beneficiary)	3370244.1	44.5	14948.2	1.8	177836.5	21.4	268336.86	32.2	831365.8
4	Central Assistance Sanctioned (`)	59095	29.2	5716.1	2.8	29245.5	14.5	108217.49	53.5	202274.09
	%	16		38.2		24.3		40.33		24.3
5	Central Assistance Released (`)	48095	39	2592	2.1	12068.8	9.8	60595.09	49.1	123350.9
6	Houses Sanctioned (Nos.)	2536864	21.1	21.1	352862	2.9	1932052	16.1	7216777	60
7	Houses Grounded for Construction	2190864	21.2	641510	6.2	1334123	12.8	6200974	59.9	10357471
	%	86.4		181.8		68.5		85.95		86
8	Construction of Houses Completed/ Delivered	2076864	33.1	490260	7.8	660425	10.5	3051282	48.6	6278831
	%	94.8		76.4		49.9		49.2		60.6

Source: Ministry of Housing and Urban Affairs, 2023

Mission (Fig. 3). The ICCC coordinates multiple municipal functions, disaster /resilience, traffic and transportation, environmental monitoring, weather, and disaster risk reduction.

DISASTER RISK REDUCTION (DRR)

India has been playing a leading role in the field of disaster risk reduction (DRR). As announced at the Sendai framework review meeting at the United Nations in May 2023, India has set the priorities of DRR for G-20 Nations, viz. early warning for all, resilient infrastructure, improving finances and capacities for DRR response and eco-system-based approaches. The spatial and non-spatial data are abstracted and synthesised to prepare a comprehensive District Hazard Risk Map using of new technologies for disaster risk reduction, as given in Table 2.

The PM Gati Shakti Master Plan, launched in 2021, provides valuable lessons for planning of sustainable infrastructure for seamless movement of people, goods and services. It leverages new technologies, breaking the silos of departmentalisation to achieve ease of doing business. PM Gati Shakti is based on the six core principles, incorporating infrastructure such as laying utilities during the planning phase, enhancing connectivity to help seamless movement, ensuring ecological focus on conservation of forest, biodiversity, rivers, etc., faster land acquisition and expeditious clearances (Figs. 4&5).

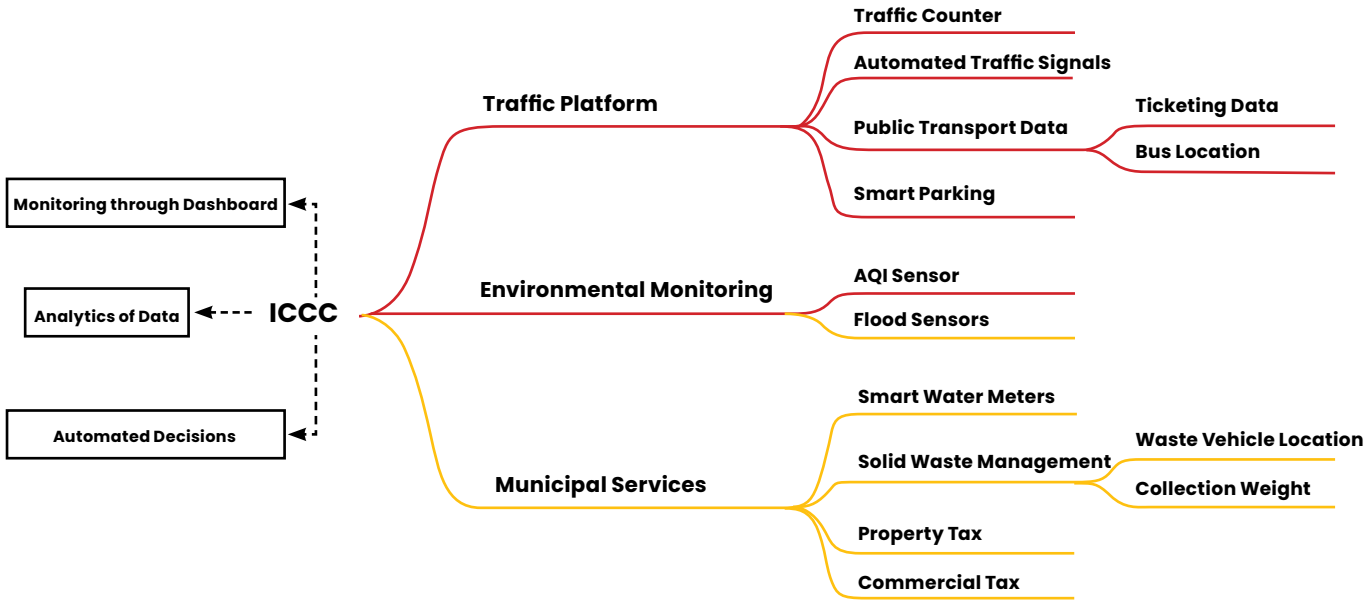

Fig. 3: Model of the Integrated Command and Control Centre (ICCC)

Source: Parkar, Khaliq and Uttara Purandare (2023) Decoding Digitization of Urban Governance in India, Centre for Policy Research, New Delhi

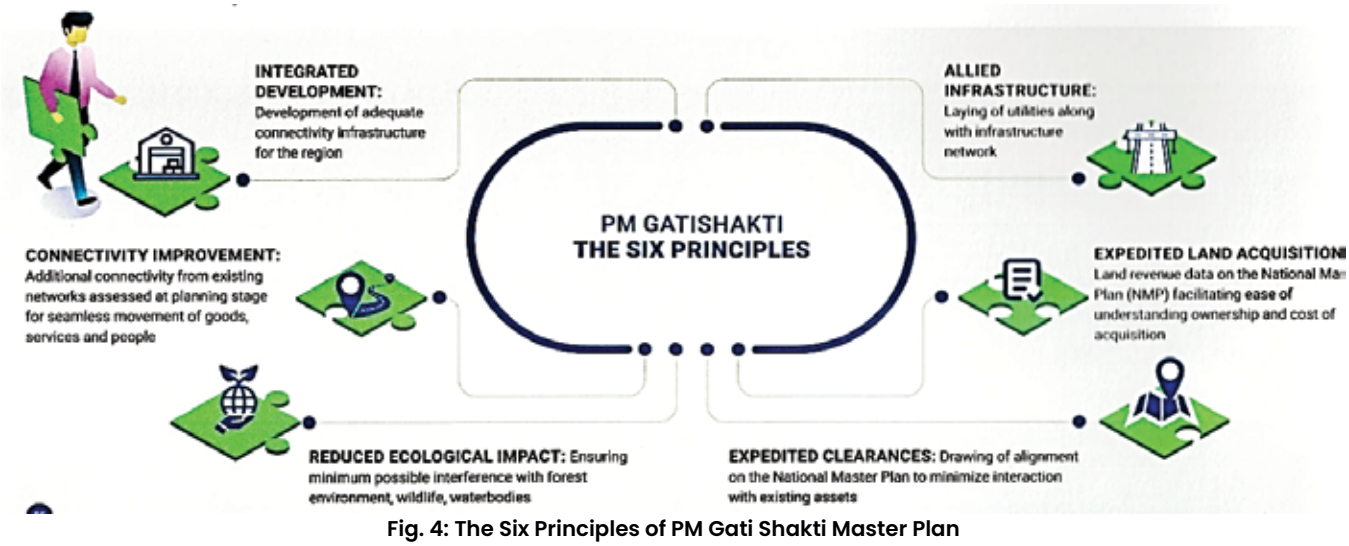

Fig. 4: The Six Principles of PM Gati Shakti Master Plan

Source: Ministry of Commerce and Industry, GOI 2023

Prioritisation, Synchronisation and coordination are made possible by focusing on each aspect of a project in granularity on one platform, with visibility across stakeholders. This also helps drive faster prioritisation and easier synchronisation to avoid delays. The detailed analysis from the data layer and the tools ensures better optimisation of project and quick interventions for closure. The Gati Shakti Master Plan has coordinated with the Indian Space Research organisation (ISRO) for spatial planning, engaging BiSAG (Bhaskar Acharya National Institute for Space Applications) and Geo-Informatics. This GIS platform builds over 1200 data layers from Central Government Departments and 755 from the States/Union Territories. Multi-modal integration, last mile connectivity and e-governance are the pillars of PM Gati Shakti Master Plan. All the modes of goods and passenger transport are digitised and pooled and adopt Intelligent Transport Systems and transit-oriented development. This envisages road design with dedicated tracks for

Table 2: New Technologies for Disaster Risk Reduction

Phase	Activities	Example Technology
Mitigation	Geospatial data of built environment Baseline information of natural ecosystem Land use planning and risk management Community engagement	• Remote sensing for documentation all the buildings, location, age, plans, category and land use • Computer modelling of risks and vulnerability • Drone supported surveys • Satellite and GIS to map natural ecosystems • Model and land use changes • Real Time warning systems using mobile phone • Mobile apps for local communication • Information campaign via digital media
Preparedness	Meteorological observation Spatial Mapping Early warning Systems Stockpiling Identifying vulnerable buildings and infrastructure	• IoT connected and AI enabled monitoring • Satellite based technologies to gather geospatial and Meteorologicaldata • Digital mapping, GIS, Open Street Maps, hazard maps • Real Time monitoring of risks • AI enabled cross checking of data • Mobile based warning apps • Digital communication systems to inform people • AI enabled forecasting, digital accounting, and monitoring tools • Digital inventory of stockpiles • Geospatial surveys using software such as Open Data Kits
Response	Emergency services such as search and rescue evacuation Provision of shelters and basic needs Surveillance Communication	• Drones for aerial surveillance • Social media monitoring • Geospatial maps • Apps to inform people about shelter facilities • Communication infrastructure • GIS mapping and aerial surveillance • Broadcasting emergency messages on mobile phones • Social media platforms
Recovery	Livelihood support Establishment and rehabilitation of basic services Reconstruction Planning	• Cash transfers via electronic/digital tools • Real-time updates on the restoration of services • Digital tools to coordinate processes, construction and operations. • Digital surveys, mapping and monitoring using drones

Source: Author

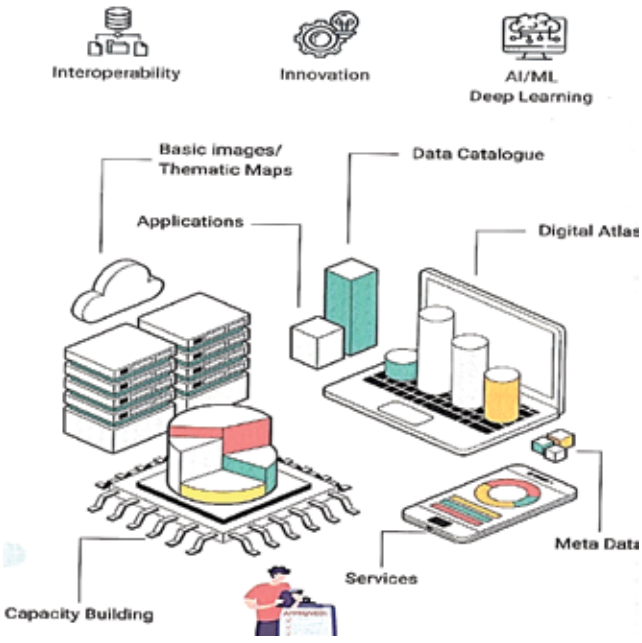

Fig. 5: Emerging Technologies for PM Gati Shakti Master Plan

Source: Ministry of Commerce and Industry, GOI 2023

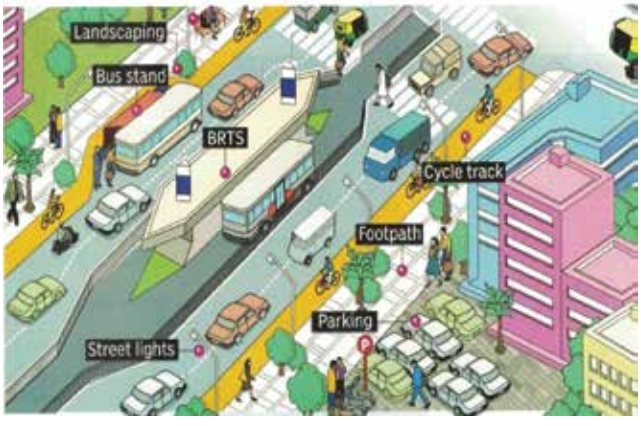

Fig. 6: Road Design with Dedicated Cycle, BRT Tracks and Footpaths

Source: DUAC/Amit Ghoshal (2015), Punjabi Bagh Project, DUAC, New Delhi

Fig. 7: Highway/Roads/Railway Lines must provide Safe Crossing for pedestrians, wheelchairs, prams and animals

cycles, pedestrians and public transport (Fig. 6). The highways, roads and railways provide for safe crossing of pedestrians, prams, wheelchairs and animals (Fig.7).

The Whole Government Platform enables easier collaborations across departments, dramatically simplifying the planning process while ensuring the design that is mindful of all economic and social aspects. Area Development Approach has been conceptualised to create convergence of adequate infrastructure catalysing socio-economic and sustainable development within a geographical location. Major areas of planning include Integrated Command and Control Centre (ICCC), physical infrastructure, like energy, water supply, sewerage/sanitation, drainage, waste recycling, roads, parking, economic/work spaces and social amenities such as education and hospitals, parks, art and cultural spaces, tourism, etc.

National Monetisation Pipeline with a budget of Rs 6 lakh crore during 2022-25, deals with a host of national services including railways. Railways Infrastructure Investment Trust (InvITs) is anchored by the Dedicated Freight Corridor Corporation (DFCC) for redevelopment of railway stations, warehousing, commercial and entertainment hubs. In the budget (2023-24) 1275 railway stations are being redeveloped. The funds have been allocated for Rapid Train Projects, Railway Bridges, High-Speed Railway Corridors, Dedicated Freight Corridors (3581 km), Hydrogen Powered Trains, Gati Shakti Units and Transit Oriented Development. The investments go hand in hand with innovations, viz. digitisation of railway supply chain, artificial intelligence, biometric token system, contactless travel, driverless train operations, head on generation system, LIDAR technology, online monitoring of rolling stock, cyber security and Kavach safety technology.

ACCELERATED AND SUSTAINABLE ECO-CITY

The pillars of the Smart Cities Mission, Gati Shakti Master Plan and the National Monetisation Pipeline is the sustainability and circular economy. These provide important lessons for urban planning, such as better synchronisation, leveraging, bridging

gap between planning and implementation, adoption of new technologies and public-private partnerships.

The Sustainable Development Goals of the United Nations (2015) focus on making cities and communities inclusive, safe, climate and disaster resilient and sustainable. At the United Nations Conference of the Parties (COP 26, Glasgow, 2021). PM Narendra Modi committed to raise the India's non-fossil fuel energy from 160GW at present to 500 GW by 2030 and 50% of the power requirement to be met by the renewables. Solar modules will reduce the carbon intensity of the economy to less than 45% and achieve net zero emissions by 2070 by clean technologies, like electric transport, ethanol blending in gasoline, solar photovoltaic and batteries, which would play a critical role in its decarbonisation.

At the COP 27 (2022, Sharm-el-Sheikh, Egypt), India launched its Low Emission Development Strategy (LT-LEDS) by a transition towards expanding renewable energy, strengthening power grid, and energy conservation, rational use of fossil fuels, nuclear energy, green hydrogen, fuel-cells, and biofuels. India's LiFE (Lifestyle for the Environment) Mission, Coalition for Disaster Resilient Infrastructure (CDRI) and Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI) underlined to achieve a balance among the people, infrastructure development, resilience and environment.

The 28th Conference of the Parties (COP28, 2023, Dubai) agreed to accelerate short-term climate actions and operationalization of the Loss and Damage Fund. A major focus has been to strengthen climate action and strengthening the sustainability challenges in the urban sector, energy, transportation, buildings and construction.

The paradigm of sustainable development has to synthesis with its humane, economic, environmental, cultural and social aspects, protecting the rights of the poor, informal sector, women and vulnerable communities and provide them with housing, water, sanitation, electricity and jobs. It seeks to integrate human and physical geography by interaction between society and natural environment and a shift from unsustainable mega city to a circular, sustainable eco-city (Fig 8).

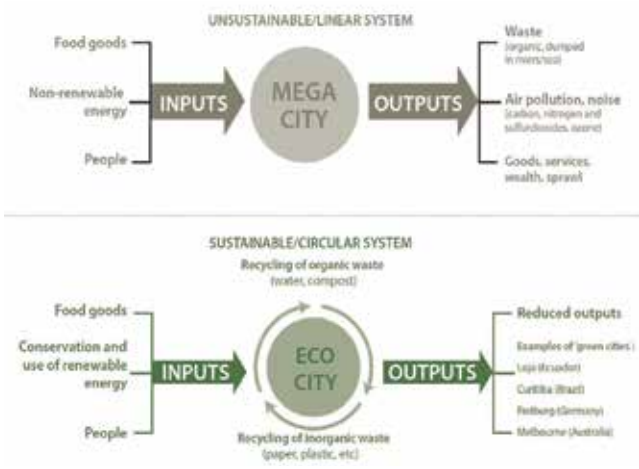

Fig. 8: City as a System

Source: UNESCO & MGIEP (2017) Textbooks for Sustainable Development, A Guide to Embedding, UNESCO and Mahatma Gandhi Institute of Education, Peace and Sustainability, New Delhi

URBAN INNOVATIONS AND NEW TECHNOLOGIES

New age technology is changing the script of urban planning and management. As demonstrated by Smart Cities Mission and PM Gati Shakti Master Plan, the new technology is vital for delivery with speed, scale and skills. The ICT (Information and Communication Technology), Artificial Intelligence, Big Data Analytics, Machine Learning, Deep Learning, blockchain, GIS, GPS, etc. are disrupting the urban processes by intelligent and smart planning, infrastructure and services, transport systems, land management and enforcement.

The breakthrough in digital technology and informatics has multiplied space, energy and time. It is time that new forms of energy, services, construction and recycling are evolved, which are characterized by online exchange of information, interactions, dynamic networks and floating nodes. Global positioning systems and satellite-guided GPS devices are increasingly being used for urban surveys, planning and laying of services. By data analytics, it is possible to plan and implement the projects with precision and accuracy. Integration of land use, utilities, transport and building on a common network helps optimize space efficiency and energy use. By developing sector–focused, cluster–based intelligent city strategies, territories can set in motion innovation mechanisms and

enhance sustainability of their services and systems.

According to NASSCOM- McKinsey Report 'Sustainability Opportunity for Tech Services and Solutions' (2022) digital technologies, such as Cloud, IOT, Blockchain and AI (Artificial Intelligence), can be critical in evolving sustainability solutions, energy management, real estate and buildings, benefitting bottom lines and accelerating deliveries.

It is estimated that during next 25 years, the number of buildings in India will be multiplied six times. These have to be net zero and energy efficient. This involves upgrading the power monitoring system, unlocking renewables, smart waste management/recycling with easy to digest dashboards, which provide real time measurement of power load.

Under the Geospatial Policy 2022, 3D Digital Twins provide a technology platform for 3D modelling and virtual representation of an object or a system that uses sensors, drones, 5G Internet of Things (IoT) and industrial IoT (IIot) data. It applies advanced analytics, machine learning and artificial intelligence (AI) to derive real time insight into the performance, operation and sustainability of a project or a city (Fig 9). These cover buildings, energy, low carbon zones and tri-generation energy systems (combining power, cooling and heating). Integration of GIS with energy, transport, water and air enable sustainable development.

The MOHUA and NIUA, along with the Bureau of Indian Standards (BIS), have developed 15 Smart City Standards. These focus on the use of new technological systems, such as GIS, sensors and networks. The Unified Digital Infrastructure – ICT Reference Architecture Standards (IS 18000:2020) is a comprehensive document for digitalization of urban practice. It defines the "Unified Digital Infrastructure" as the sensors, data systems, IoT systems and platforms. Smart Cities – GIS (IS 18008: 2020) standards define key formats for GIS platforms.

The Niti Ayog has built National Data Analytical Platform which provides data sets in machine readable formats. This can be used for planning and policy making such as Aspirational District Programme.The Ministry of Housing and Urban Affairs (MOHUA) launched the National Urban Digital Mission (NUDM), which aims to push for the outcome-based digitalization of urban planning

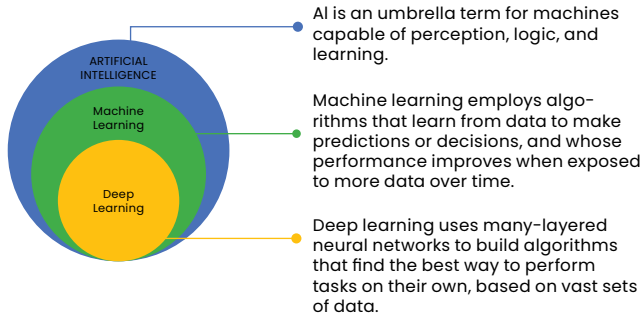

Fig. 9: Components of Artificial Intelligence

Source: Verma, Seema, Towards Data Science, Shashwat (2022) TERI, New Delhi

and governance (Fig. 10). The Data Acquisition and Exchange Programme enables data to be exchanged, analysed and marketed on various portal along with National Urban Learning Platform, Smart Code, National Urban Governance Platform andUrban Platform for Delivery of Online Governance (Fig.11).

An intelligent geo-portal can bring together various line departments on a platform for e-service delivery. This yields better co-ordination and exchange of information, cost and time management. Citizen engagement becomes much easier and viable by virtual town halls. It can also help in the integration of citizen participation, governance and online consultation over plans and programmes of local development.

Smart chips and systems can be embedded

Fig. 10: Key Drivers for Digitisation for Sustainable, Inclusive and Resilient Urban Planning and Data Driven Decision Making

Source: NIUA (2023)

almost in every urban service and structure, making them smart and intelligent. The "smart nodes on a smart grid" concept can provide services to enhance users experience, such as high-speed communication and data management, carbon-emission accounting and performance objectives.

Fig. 11: Urban Platform for Delivery of Online Governance (UPYOG)

Source: NIUA (2023)

Blockchain is a new age technology for urban development and management, real estate, title transfer, etc. A digital ledger is a geographically distributed database that is shared and synchronized across a network of participants. In a blockchain structure the data is stored in blocks, linked and secured by cryptography for handling identities, contracts and assets. It is based on a hash algorithm that converts data into a block, that can simplify the complex and open to manipulation paperwork in property records.

UNIFIED DEVELOPMENT CONTROLS AND BUILDING REGULATIONS

With the passage of time development control regulations and building byelaws have become too complex together with several regulatory authorities controlling the following:

- Development Control Regulations: FAR-Ground Coverage-Height-Setbacks, Transferable Development Rights (TDR) and Accommodation Reservation regulations
- Regulations for Land Pooling and Land Rights
- Building Byelaws
- Fire Safety Regulations
- Form Based Codes
- LOP/Layout Plan/Sub-Division Regulations
- Regulations for Unauthorised Colonies, Villages, Special Area, Redevelopment
- Transit Oriented Development, Traffic and Transport/Parking Regulations
- Mixed Use Regulations
- Reservation of 10% Private Land for Amenities, Open Spaces and Infra Services
- EIA Regulations/ Green Building Regulations
- ECBC 2017 (Energy Conservation)
- Heritage Regulations
- Heat Mitigation, Climate and Disaster Resilience Regulations

All these need to be put on a common digital platform integrating planning, environmental and building regulations and management.

FINANCING AND MOBILISING INVESTMENTS

The McKinsey report estimates that nearly 45% of the urbanfinancial requirements can be met through various land and asset monetization strategies, such as development charges, impact fees, building fees, land use conversion charges and sale of Floor Area Ratio (F.A.R) or air rights. To encourage optimum use of land and densification by higher FAR, a two-tier FAR structure can be adopted with a basic FAR bundled with property right and the remaining to be purchased to enable value capture. This has been used to subsidise in-situ slum rehabilitation, whereby 40% of land/FAR for market sale can finance the whole project, e.g. Kathputli Slum Rehabilitation Project in Delhi. Other innovative tools to mobilise the investments can be green municipal bonds, Urban Infrastructure Development Fund, Tax Increment Financing, Toll Tax, Land Banking, Infrastructure Investment Trusts, EPC Contracts, Value Capture Finance, Impact Fees, and Betterment Levy.

Impact fees are levied on new constructions in an area where large public investments such as major roads and highways, metro rail, industrial corridors, ports, airports, and other public infrastructure are undertaken. An example of impact fee is new developments within the 1 km wide Growth Corridor (GC) on the 162 km Outer Ring Road (ORR) around Hyderabad. The

impact fees are higher for commercial use, and increases with the FAR. However, there had been a wide gap between the estimated and actual recovery. In Delhi, there have been glaring shortfalls in collecting the Betterment Levy, Land Use Conversion Charges, Mixed Land Use Charges and Parking Fees.

CONCLUSION

By 2047, India will be world's third largest economy with a GDP of $36 trillion. It would add about 400 million urban population to its existing 432 million. For a rapid trajectory of urbanisation, a major challenge is to interface the economic and ecological eco-systems. This calls for radical transformation and integration of technologies for accelerating inclusive, resilient cities and infrastructure, India with a demographic dividend and youth power, technological advantage and a robust economy can unleash its urban potential by adopting circular and new technologies, along with harmonised and innovative urban financing, legal and governance frameworks. These are the cornerstones for Viksit Bharat.

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CHALLENGES AND INNOVATIONS IN URBAN PLANNING FOR CLIMATE RESILIENCE

Hitendra Mehta* And Ayusha Batham**

Abstract

Climate change is a major challenge for ecosystems, economies, and communities. This abstract explores the complex relationship between climate change and resilience. It emphasizes innovative strategies to enhance adaptability and reduce adverse effects.

Climate change poses a serious threat to urban areas, demanding a strategic rethinking of resilience frameworks to ensure the sustainable development of cities. This abstract examines the complex link between climate change and urban resilience, with a focus on the challenges faced by cities and the transformative strategies required to adapt.

Sustainable urban planning and design are crucial for urban resilience. Integrating green spaces, implementing climate-responsive infrastructure, and adopting eco-friendly technologies contribute to cities' adaptive capacity while promoting environmental sustainability. The abstract discusses successful case studies illustrating the positive outcomes of such integrated approaches in enhancing urban resilience. Emphasizing innovative technologies, community engagement, and integrated policies, the abstract highlights proactive steps to improve urban planning, developing resilient infrastructure, establishing early warning systems, and fostering inclusive urban development.

In conclusion, the abstract emphasizes on integrating climate change into urban planning and resilience initiatives. Through the adoption of sustainable practices, community engagement, technology utilization, cities can proactively adapt the changing climate, securing a resilient and sustainable urban future.

INTRODUCTION

Climate change presents a formidable challenge with far-reaching implications for ecosystems, economies, and communities worldwide. This comprehensive paper explores the intricate relationship between climate change and urban resilience, focusing on the urgent need for innovative strategies to enhance adaptability and reduce adverse effects. As cities face an escalating threat from climate change, a strategic rethinking of resilience frameworks becomes imperative for ensuring the sustainable development of urban areas. This paper delves into the complex link between climate change and urban resilience, addressing the challenges faced by cities and proposing transformative strategies to adapt effectively.

The profound impact of climate change on urban areas, emphasizing the necessity for cities to strategically reassess their resilience frameworks. The discussion centers on the threats posed by climate change to the urban environment, infrastructure, and the well-being of urban populations. It highlights the urgency of adopting proactive measures to address the challenges and uncertainties associated with a changing climate. This research paper delves into the conceptual underpinnings of urban resilience, examining its interconnected elements and shedding light on its practical implications for sustainable urban development.

**CMD Mehta & Associates LLP, Indore, M.P.*
***Urban Planner at Mehta & Associates LLP, Indore, M.P.*

CHALLENGES IN URBAN AREA

Urban areas face a myriad of challenges that necessitate a focused approach to urban resilience. Addressing these issues is crucial for creating cities that can adapt, recover, and thrive in the face of diverse stresses and shocks. Urban areas are facing multifaceted challenges that demand a resilient response for sustainable development:

In navigating these challenges, urban resilience becomes not only a strategic imperative but a

fundamental philosophy for urban development. A holistic approach that integrates environmental,

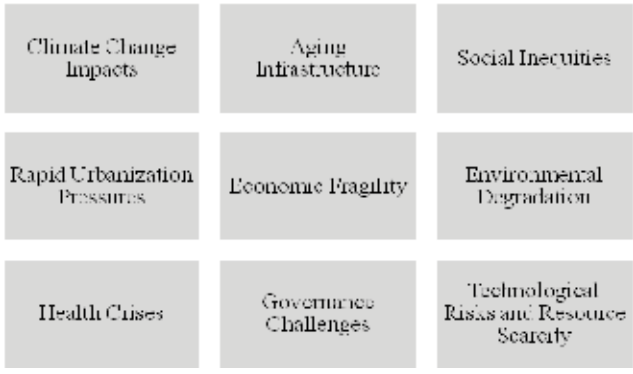

Fig. 1: Challenges in Urban Area

Source: Author, 2024

social, economic, and technological dimensions is essential to fortify cities and urban systems, ensuring their ability to thrive in the face of an evolving and uncertain future.

As the UN World Urbanization Prospects project foresees 68% of the world's population residing in cities, the urgency for resilient urban infrastructure becomes paramount. Presently, 70% of cities are already grappling with the impacts of climate change, with over 90% of urban areas situated in coastal regions facing risks like flooding due to rising sea levels.

Economic, social, and climate resilience are the pillars of urban resilience, requiring innovative fiscal frameworks, strengthened social safety nets, and environmentally friendly investments. This introduction sets the stage for a comprehensive exploration of urban resilience, emphasizing the imperative of proactive strategies to address the multifaceted challenges posed by urbanization, climate change, and globalization.

Urban resilience is widely recognized as a critical objective for both adaptation and mitigation efforts in cities and urban regions. The growing emphasis on resilience in urban planning signifies a departure from a reactive stance to a more anticipatory and strategic approach, wherein cities are not merely responding to challenges but actively fortifying themselves against future uncertainties.

URBAN RESILIENCE

Urban resilience, in this context, encompasses the capacity of a city or urban system to withstand a diverse array of shocks and stresses, with climate change recognized as just one among many challenges confronting urban areas.

Consequently, urban resilience is a comprehensive concept embracing both "hard indicators," such as infrastructure and transportation, and "soft indicators," including economic and social aspects. Initially applied in the physical and socio-economic domains, urban resilience theory primarily focused on physical resilience, pertaining to the robustness of infrastructure, economic resilience, associated with the health of economic development, and social resilience, related to the recovery capacity of communities and individuals.

As urban challenges have become more prominent, urban resilience research has shifted its focus to enhancing cities' capacities to navigate natural disasters and socio-economic risks amidst the backdrop of climate change, globalization, and urbanization. This enhanced capacity encompasses proactive measures taken by cities before, during, and after destructive events to mitigate their adverse impacts. It also includes the ability of cities to maintain or restore their intended functions in the face of disturbances on temporal and spatial scales. In essence, urban resilience emerges as a fitting response to the escalating risks in urban areas.

RESILIENT CITY TRANSITION

"Resilient City Transition" refers to the intentional and strategic shift that urban areas undergo to enhance their resilience in the face of various challenges, including but not limited to climate change, socio-economic shifts, and environmental pressures (Fig 2). This transition involves a comprehensive and dynamic process aimed at fostering adaptive capacities, promoting sustainability, and ensuring the well-being of residents. Several key components characterize a Resilient City Transition:

- **Integrating Ecological Resilience into Urban Planning**

  Planning cities and designing them in a sustainable way is crucial for making cities strong and able to withstand challenges. It explores the integration of green spaces, climate-responsive infrastructure, and eco-friendly technologies as crucial components contributing to cities' adaptive capacity while concurrently promoting environmental sustainability. The discussion underscores the need for cities to prioritize sustainable urban planning to effectively navigate the impacts of climate change.

  Innovative technologies, community engagement, and integrated policies as key elements in developing proactive measures for improved urban planning. It explores successful initiatives, such as the establishment of resilient infrastructure, implementation of early warning systems, and fostering inclusive urban development. By emphasizing the importance of a holistic approach that encompasses various facets of urban life, from technological advancements to community empowerment, this section provides insights into building resilient urban systems.

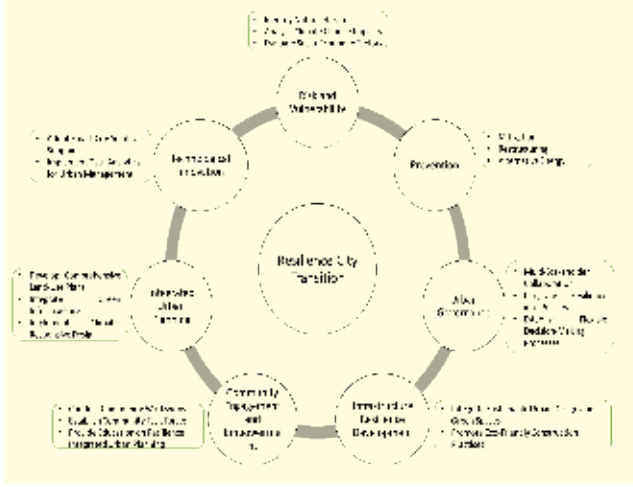

Fig. 2: Resilient City Planning Framework

Source: Jabareen, October 2014

PLANNING STRATEGIES

Creating urban resilience involves employing a range of strategic planning initiatives. Implementing a holistic approach to urban planning is paramount in fostering urban resilience. Transit-Oriented Development (TOD) stands as a cornerstone, advocating for compact, mixed-use communities centered around public transit, reducing reliance on private vehicles and enhancing accessibility. Mixed land use planning complements TOD by fostering diverse urban spaces, creating self-sufficient communities capable of weathering disruptions. Prioritizing Non-Motorized Transport (NMT) through bike and pedestrian infrastructure not only promotes healthier lifestyles but also ensures alternative means of mobility, vital during emergencies. Planning urban green infrastructure contributes to a resilient environment by mitigating climate change impacts, reducing the urban heat island effect, and providing recreational spaces. Climate response planning further fortifies cities against the challenges posed by climate change, integrating adaptive measures into urban policies. Lastly, promoting sustainable public transport aligns with environmental goals, reducing the carbon footprint and enhancing urban mobility, thereby solidifying the foundation for cities that are adaptable, sustainable, and resilient in the face of evolving challenges.

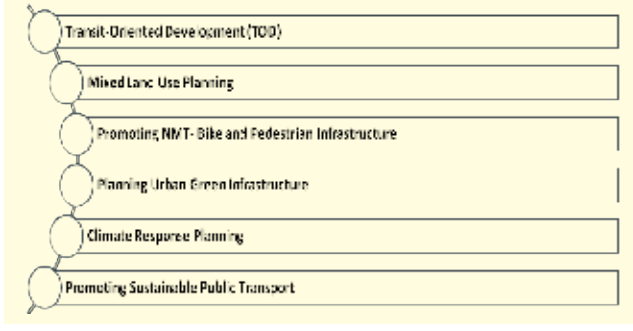

Fig. 3: Urban Planning Strategies for Urban Resilience

Source: Author, 2024

- **Transit-Oriented Development (TOD)**

  Transit-Oriented Development (TOD) serves as a linchpin in fortifying urban resilience by fundamentally reshaping the fabric of cities. At its core, TOD strategically centers mixed-use developments around public transportation hubs, cultivating interconnected, vibrant communities. By encouraging reliance on efficient public transit rather than individual

vehicles, TOD reduces congestion, lowers emissions, and establishes a more sustainable urban transport system. This shift not only addresses environmental concerns but also bolsters cities against the impacts of climate change. Moreover, the concentration of amenities and services around transit nodes ensures that residents have easy access to essential resources, fostering self-sufficient communities. TOD's emphasis on walkability and connectivity further enhances the ability of urban areas to withstand disruptions, as residents can efficiently navigate their surroundings during emergencies. In essence, TOD emerges as a pivotal urban planning strategy, promoting resilience by creating agile, sustainable, and well-connected urban landscapes.

- **Mixed Land Use Planning**

  Mixed Land Use Planning emerges as a key catalyst in fortifying urban resilience by promoting a diversified and interconnected urban fabric. This approach transcends traditional zoning practices by strategically integrating residential, commercial, and recreational spaces within defined areas. By fostering compact, walk able communities where residents can live, work, and access essential services in close proximity, mixed land use planning significantly reduces dependency on extensive commuting during disruptions. This inherent diversity ensures that even in challenging circumstances, such as economic downturns or unexpected events, local economies remain robust. The concentration of varied land uses not only enhances accessibility for residents but also cultivates vibrant neighbourhoods capable of withstanding shocks. In times of crisis, the availability of essential services within mixed-use developments ensures that communities can adapt swiftly and maintain a level of self-sufficiency. Ultimately, mixed land use planning stands as a resilient urban strategy, fostering agile, well-connected, and adaptable cities that thrive in the face of dynamic challenges.

- **NMT- Bike and Pedestrian Infrastructure**

  Promoting Non-Motorized Transport (NMT) through the development of bike and pedestrian infrastructure emerges as a pivotal strategy in bolstering urban resilience. This approach prioritizes creating environments where walking and cycling are not just recreational activities but integral components of daily mobility. Robust bike lanes, pedestrian-friendly pathways, and cycling infrastructure reduce dependency on conventional transportation, providing resilient alternatives during disruptions like fuel shortages or traffic congestion. The emphasis on NMT not only fosters healthier and more sustainable modes of transportation but also ensures that communities have agile and accessible means of mobility in times of crisis. Moreover, these initiatives enhance social cohesion by creating walk able neighbourhoods, contributing to community resilience. By integrating NMT into urban planning, cities invest in adaptable and environmentally conscious transportation systems, making them more resilient to unforeseen challenges while fostering a healthier and more connected urban lifestyle.

- **Urban Green Infrastructure**

  The planning and implementation of urban green infrastructure stand as a cornerstone in fortifying urban resilience. Urban green spaces, including parks, green roofs, and sustainable landscaping, contribute significantly to the overall well-being and adaptability of a city. Green infrastructure mitigates the urban heat island effect, reduces the risk of flooding, and enhances environmental sustainability. During extreme weather events or other disruptions, these green areas act as natural buffers, absorbing excess water, reducing temperatures, and providing essential ecosystem services. Beyond their environmental benefits, urban green spaces offer recreational opportunities, promoting community well-being and mental health. By strategically integrating green infrastructure into urban planning, cities not only enhance their ability to withstand shocks and stresses but also foster a more sustainable and livable urban environment for their residents.

- **Climate Resilient Planning**

  Climate response planning, coupled with mitigation strategies, restructuring, and the integration of alternative energy sources, plays a pivotal role in fortifying urban resilience. Cities face increasing challenges posed by climate change, including extreme weather events, rising temperatures, and environmental degradation. Climate response planning involves the development of strategies to adapt to these changes while mitigating their impacts. Restructuring urban infrastructure to withstand climate-related stocks, such as floods or heatwaves, is crucial. The incorporation of alternative energy sources, such as solar or wind power, not only reduces the carbon footprint but also enhances energy resilience, ensuring a more reliable energy supply during disruptions. By embracing these measures, cities not only contribute to global climate mitigation efforts but also build adaptive capacities, making urban areas more robust and better equipped to navigate the uncertainties associated with a changing climate. These strategies collectively contribute to the creation of urban environments that are not only sustainable but also resilient in the face of evolving climate challenges

- **Promoting Sustainable Public Transport**

  Promoting sustainable public transport emerges as a linchpin in advancing urban resilience by fostering an efficient, environmentally conscious, and adaptable urban transportation system. Sustainable public transport, such as buses, trains, and electric trams, reduces dependence on individual vehicles, mitigating traffic congestion and lowering carbon emissions. During disruptions like fuel shortages or traffic blockages, well-established public transport networks provide a reliable alternative, ensuring continued mobility for urban residents. Moreover, sustainable public transport initiatives contribute to economic resilience by minimizing the impact of rising fuel costs on both individuals and businesses. By prioritizing these modes of transportation, cities not only address environmental concerns but also enhance overall urban resilience, creating interconnected, accessible, and eco-friendly transportation systems capable of withstanding various shocks and pressures. This strategic approach aligns with the broader goal of building cities that are both sustainable and resilient in the face of dynamic challenges.

CASE STUDY: MUMBAI METROPOLITAN REGION

The Mumbai Metropolitan Region (MMR) in Western Maharashtra, India, is the world's fourth-largest urban agglomeration, characterized by rapid population growth, reaching 27 million by 2025.

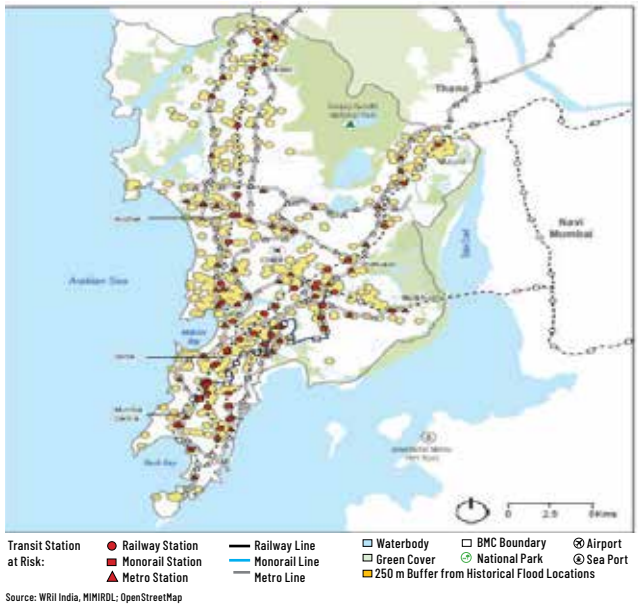

Fig. 4: Mass Transit Stations with Limited Physical Access during Floods

Source: WRI India, MMRCL Open Street Map

High-density urbanization and informal settlements strain infrastructure. Uncoordinated development and land-use conversion threaten arable land, with built-up areas projected to cover 47% by 2050.

Mumbai Metropolitan Region faces vulnerability due to its coastal location and land reclamation, increasing flood risks and urban heat island effect. With decreasing open land, rainwater percolation is hindered, straining infrastructure and sanitation services. Climate change

exacerbates flooding, heatwaves, and rising sea levels, impacting marginalized communities disproportionately.

First steps towards developing a risk-informed urban planning framework using a three-step qualitative research process-

- Present the existing knowledge landscape around risk-informed urban planning and infrastructure resilience.
- Establish the requirements and constraints planners face in translating climate and disaster variables into urban plans and infrastructure policies.
- Make the first steps towards the development of a risk-informed urban planning framework. The framework is expected to be utilized for a more extended research project to develop future land-use scenarios for Mumbai under climate change.

MMR's planning instruments, including the Regional Plan and Development Plan, are updated every 20 years. However, the 2016-2036 Regional Plan lacks detailed strategies for addressing climate change impacts. Criticisms include the plans' prescriptive nature and lack of integrated visions. Strategies such as creating water networks and green areas are proposed, but implementation details and timelines remain unclear.

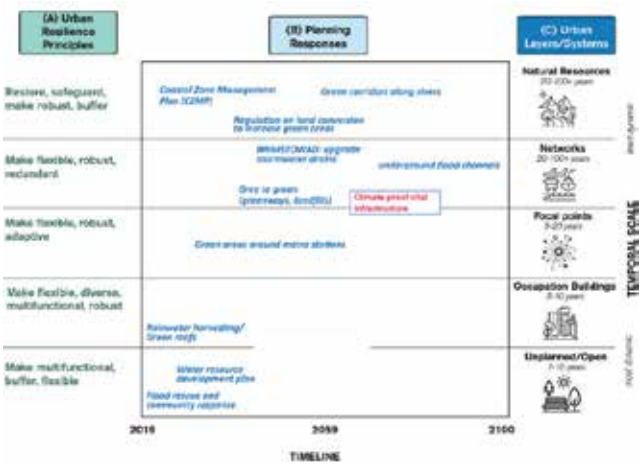

Fig. 5: Mapping climate-related planning responses for MMR

Source: Krishnan, 2021-22

Disaster and Climate-related Planning Responses

- Proposed and ongoing climate and disaster-related planning responses for the Mumbai Metropolitan Region (MMR), linked to targeted Urban Infrastructure Systems.
- Resilience principles for each system are assessed based on the responses.
- Typical responses include rainwater harvesting, stormwater drain upgrades, landscape reinforcement, and climate-proofing vital infrastructure.
- MMR's planning is primarily reactive, focusing on managing urban flooding through community response and infrastructure upgrades.
- The project aims to expand stormwater drain capacities.
- Emphasis is placed on restoring green spaces, implementing Coastal Zone Management Plans, and regulating land conversion.
- Rain water harvesting norms are enforced only in new greenfield developments, with a lack of integrated strategies for capturing rainwater at smaller spatial scales.

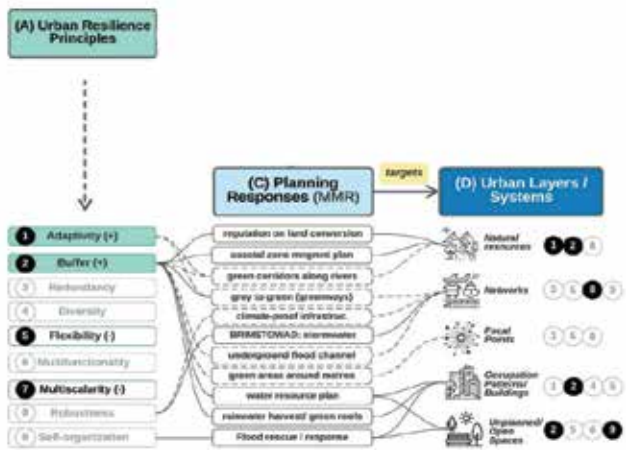

Fig. 6 : The conceptual urban planning framework for Urban Resilience

Source: Supriya Krishnan

This study develops a theory for risk-informed urban planning, merging urban resilience and planning responses within the Mumbai Metropolitan Region (MMR). The MMR lacks strategic

actions integrating climate and development priorities, relying on reactive measures. Informal urban growth complicates planning responses. Conflicts arise between increasing density and ecological planning. MMR's single-scenario planning overlooks future variations, necessitating predictive and normative planning approaches for resilient urban development.

CONCLUSION

In conclusion, the intricate relationship between climate change and urban resilience demands innovative and transformative strategies for sustainable urban development. Urban areas face various challenge, ranging from climate change impacts and aging infrastructure to social inequities and economic fragility. Urban resilience emerges as a strategic imperative, necessitating a holistic approach that integrates environmental, social, economic, and technological dimensions. The growing emphasis on resilience in urban planning signifies a shift towards proactive and strategic governance models. The conceptual framework of urban resilience encompasses the capacity of cities to absorb shocks, adapt to changes, and positively transform, emphasizing the interconnected elements of environmental sustainability, social equity, economic stability, and effective governance. Strategies such as Transit-Oriented Development, mixed land use planning, non-motorized transport, urban green infrastructure, climate response planning, and sustainable public transport contribute to building resilient cities. The study underscores the critical need for a comprehensive and proactive approach to urban planning in addressing the multifaceted challenges posed by climate change and urbanization, particularly evident in the Mumbai Metropolitan Region (MMR). The current reactive measures and lack of integrated strategies highlight the urgency for strategic actions that prioritize the integration of climate and development priorities. By incorporating innovative strategies and adopting predictive and normative planning approaches, cities like MMR can enhance their resilience and adaptability to future uncertainties. This research lays the groundwork for a risk-informed urban planning framework, emphasizing the importance of resilience principles and their application in shaping urban infrastructure systems for sustainable urban development.

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URBAN PLANNING FOR MITIGATING CLIMATE CHANGE

Saurabh Jindal* and Dr. Indrasen Singh**

Abstract

Developing countries like India have a critical role in mitigating the consequences of climate change, a pressing global issue of the twenty-first century. Climate change is putting more and more strain on the built environment and the supporting infrastructures that sustain these populations, including buildings, water, energy, sanitation, and transportation. These systems will find it difficult to sustain a high standard of living for city residents if the current situation persists. Many urban areas worldwide, especially Indian cities, are still not planned for climate change. Thus, comprehensive and effective policies are essential to mitigate and increase cities' resilience towards climate change. This research conceptualizes the goals and approaches of the United Nations Framework Convention on Climate Change (UNFCCC) for sustainable urban development. The main emphasis of this study is to investigate the relationship between current and future climate risk, mitigation strategies, and urban planning tools for climate action in cities. This study reviews the climate risks to cities with approaches to increase urban resilience and concludes with policy recommendations.

INTRODUCTION

Climate change is defined as an alteration in the climate induced by human actions that modify the composition of the global atmosphere. According to the Inter governmental Panel on Climate Change (IPCC, 2018), human-caused global warming has increased by 1.0°C over pre-industrial levels, and might reach 1.5°C between 2030 and 2052 if present trends continue (Fig.1).

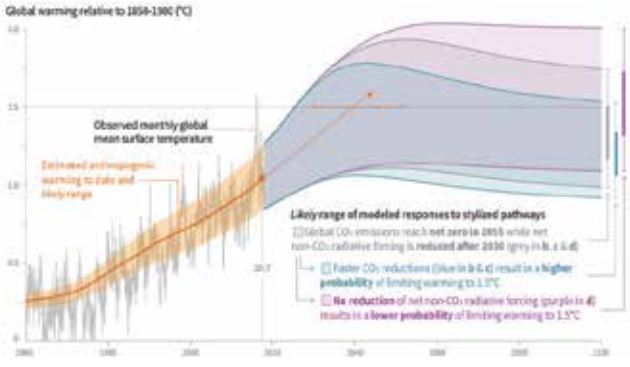


Fig. 1: Observed variations in the earth's temperature and simulated responses to stylized anthropogenic emissions and forcing routes

Source: IPCC (2018)

**Assistant Professor, National Institute of Construction Management and Research (NICMAR) Hyderabad, Telangana.*

*** Senior Professor and Dean (Academic Affairs), National Institute of Construction Management and Research (NICMAR) Hyderabad, Telangana*

The IPCC (2021) report on Climate Change – The Physical Science Basis provides evidence of changes in severe weather events such as heat waves, intense precipitation, droughts, and tropical cyclones linked to human activity (Fig. 2). This indicates that human-induced climate change is impacting a variety of weather and climate extremes globally. The main cause of the excess creation of greenhouse gases (GHGs), which cover the earth's atmosphere and trap solar heat, has been the burning of fossil fuels. Long-term sea level rise and modifications to local and global weather patterns are the two main effects of greenhouse gas concentration over time, as opposed to their gradual dissipation.

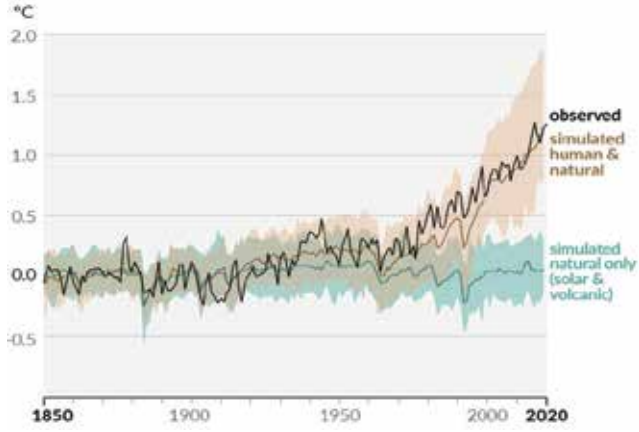


Fig. 2: Changes in the annual average worldwide surface temperature as seen and simulated between 1850 and 2020 using human & natural, and natural only factors

Source: IPCC (2021)

The IPCC (2022a) - Impacts, Adaptation, and Vulnerability report highlights the pressing need for global climate-resilient development action. It does this by emphasizing the need for comprehensive, feasible, and innovative approaches to lessen the trade-offs between adaptation and mitigation, thus advancing sustainable urban development for climate change (Fig. 3). This report provides clear conclusions on urban sustainability.

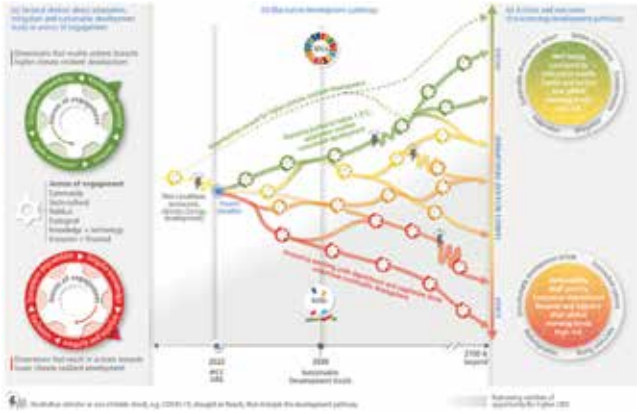
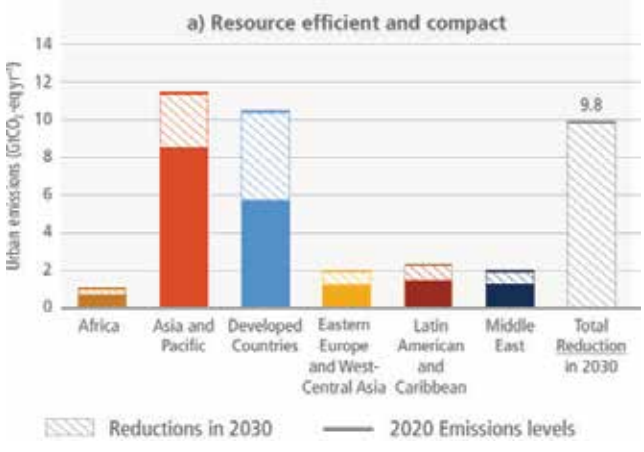


Fig. 3: Climate-Resilient Development

Source: IPCC (2022a)

The IPCC (2022b) report on Mitigation of Climate Change highlights how urban areas may cut greenhouse gas emissions and boost resource efficiency by adopting low-emission development routes that lead to net-zero carbon emissions. It can be achieved through materials, electrification, and carbon uptake. According to the study, under a scenario where there are net-zero CO_2 and CH_4 emissions, urban regions that use walk able, resource-efficient urbanization might save 9.8 $GtCO_2$-eq of urban emissions by 2030 (Fig. 4).



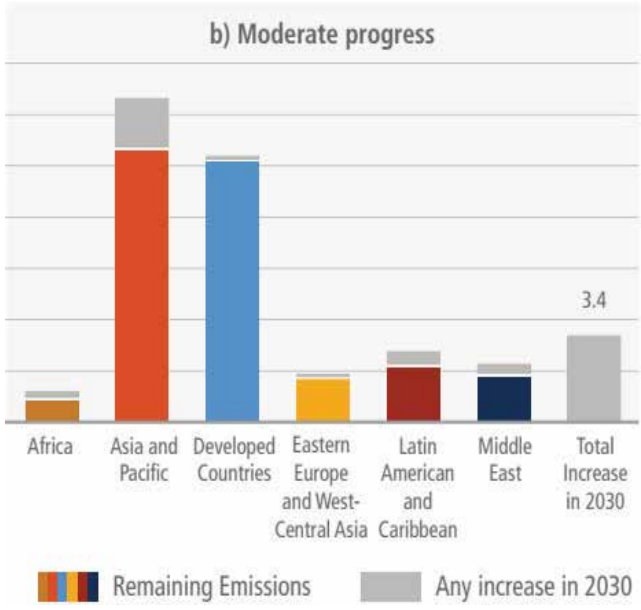


Fig. 4: Comparison of urban emissions changes under different urbanization scenarios (2020–2030)

Source: IPCC (2022b)

In comparison, modest adjustments devoid of aggressive mitigation measures would result in a 3.4 $GtCO_2$-eq rise in urban emissions from 2020 levels by 2030. The research also emphasizes how important it is to take advantage of the worldwide urbanization trend to promote climate resilient development. It further highlights that coastal cities are particularly crucial to achieving climate-resilient development and notes that integrated, inclusive planning and investments in urban infrastructure may greatly boost the adaptive ability of urban and rural populations.

The United Nations Sustainable Development Goal (UN SDG) 11 aims to create inclusive, safe, resilient, and sustainable cities and communities. It includes 11 targets for housing, transport, community engagement, heritage, accessibility, urban environments, and sustainable building and design (United Nations, 2024). The major objective is to raise the proportion of cities implementing integrated development policies, resilience to disasters, inclusiveness, resource efficiency, and climate change mitigation. UN SDG 13 intends to tackle climate change immediately, focusing on community capacity building and long-term climate adaptation (United Nations, 2024). The goal is to include climate change measures into national urban policies, allowing its linkages with national adaptation plans.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The UNFCCC is an international agreement signed in 1992 to stabilize greenhouse gas emissions and facilitate adaptation to climate change. Its membership is nearly universal, with 197 parties, including the European Union and 196 member states (UNFCCC, 2024). The Conference of the Parties (COP) under UNFCCC, the highest decision-making body, meets once a year to discuss convention resolutions, assess their status, and negotiate agreements. The Kyoto Protocol, adopted in 1997, imposes legally enforceable objectives on developed nations to reduce their emissions, with the support of programs like carbon trading and the Clean Development Mechanism (UNFCCC, 2024a). The 2015 Paris Agreement sets a target of less than 2 degrees Celsius and aims to limit global warming to 1.5 degrees Celsius over pre-industrial levels (UNFCCC, 2024b).

The UNFCCC encourages nations to create and carry out measures to cut greenhouse gas emissions from cities, such as low-carbon waste management techniques, energy-efficient construction, integration of renewable energy sources, and low-carbon transportation systems. It supports the idea of "common but differentiated responsibility" with regard to climate change, which holds that developed countries should take the lead in addressing the issue because of their greater ability to mitigate emissions and their historical record of doing so, all the while fostering sustainable development, particularly in developing countries. Intending to build cities that satisfy the requirements of the present and future generations while avoiding detrimental effects on the environment, society, and economy, it promotes funding and investment for sustainable urban development initiatives. The UNFCCC established the Global Environment Facility and the Green Climate Fund, two financial instruments to assist climate action in developing countries (UNFCCC, 2024c and UNFCCC, 2024d). Moreover, it encourages capacity building and technology transfer to improve the ability of nations to combat cities with climate change challenges. Further more, it fosters urban resilience by including climate adaptation factors in infrastructure building, planning, and disaster risk management techniques. It also encourages transparency and accountability in climate action by forcing governments to publish their greenhouse gas emissions and progress toward climate objectives, especially those for urban areas.

CLIMATE RISKS AND CHALLENGES TO CITIES

The built environment faces serious challenges from climate change, which impacts buildings, infrastructure, and urban areas. Extreme weather phenomena including storms, hurricanes, floods, heat waves, and wildfires inflict damage to roads, bridges, buildings, and other infrastructure, disrupting communities and businesses. To effectively mitigate the consequences of climate change, urban planning must address the following challenges:

- Cities are responsible for 75% of worldwide CO_2 emissions, with transportation and construction being the primary sources. Net-zero emissions are considered while establishing carbon-neutral cities, which means eliminating yearly residual GHG emissions by offsetting or removing carbon dioxide.
- The rapid and intensified rise in sea levels, causing irreversible losses, is expected to significantly impact coastal settlements and infrastructure. Utilize indigenous knowledge, sustainable land use planning, and climate adaptation strategies to foster more resilient communities.
- Urban heat islands worsen heat waves, causing health issues and increased energy consumption. They raise city temperatures, degrade air quality, and impact well-being. Green spaces, building efficiency, and cool roof initiatives can be implemented to mitigate this, enhancing air quality and reducing energy consumption.
- Aging infrastructure, including roads, bridges, and utilities, is becoming more vulnerable to harm. Maintaining the operation and safety of infrastructure requires retrofitting and strengthening it to withstand climate-related risks.
- Climate change is increasing the severity of extreme weather events, posing concerns

for individuals living in informal settlements. To reduce climate risks, the provision of adequate infrastructure, improved access to services in informal settlements, and integrate climate adaptation into urban policies for comprehensive support.

- Population migration may result from climate change-related disasters, placing a strain on infrastructure and services and exacerbating social and economic issues. To lessen the consequences of migration brought on by climate change, integrated, multi-sectoral initiatives that take into account social, economic, environmental, and governance aspects can be considered.
- The threat to ecosystems and biodiversity profoundly impacts urban areas providing essential ecosystem services. It needed to prioritize natural ecosystem conservation and restoration to increase resilience and sustainability.
- Climate change affects building design needs, which include decreasing energy use and carbon emissions while needing buildings to withstand greater temperatures, stronger winds, and more precipitation.
- Climate change impacts water availability, quality, and distribution, posing supply, sanitation, and flood management challenges. Sustainable water management strategies like conservation, recycling, and storm water management are needed.
- Climate change impacts such as flooding, landslides, coastal erosion, and heat-related disruptions on transportation infrastructure necessitate the development of resilient systems, sustainable modes of transportation, and climate considerations in infrastructure design and maintenance to mitigate potential disruptions.

URBAN PLANNING TOOLS FOR CLIMATE ACTION

Significant resilience-building efforts will be needed in the upcoming decades to mitigate climate change's impacts, prevent its worst possible outcomes, and adapt to the repercussions that cannot be avoided (Sharifi, 2021). The major discussion topics regarding mitigation policy are fuel substitution, automobile fuel economy, and energy efficiency in buildings and industry. Nonetheless, there is increasing awareness that urban planning and development might address a significant portion of the global warming issue. As the world's population and economic activities grow, urban form variables such as lower fuel use may be essential in limiting the degree of preventable climate change. The inevitable effects of climate change must be addressed with aggressive adaptation measures, such as restricting development in flood-prone and other vulnerable areas, strengthening flood control systems, expanding water and soil conservation efforts, resilient infrastructure, and nature-based solutions (Frantzeskaki & McPhearson, 2022; Perera et al., 2021; and Dhyani et al., 2020).

- **Urban Resilience**

  Urban planning and management have become increasingly important due to issues like overexploitation of natural resources, climate change, water security, economic instability, and social strife (Kushawaha et al., 2021; and Mishra et al., 2021). Resilience is the ability of social, economic, and ecosystems to withstand disastrous shocks while maintaining basic function, identity, structure, and biodiversity and allowing for adaptation, learning, and transformation (Emrich & Tobin, 2018). Therefore, urban areas must be planned to promote urban resilience to overcome these challenges.

  The climate issue is increasing catastrophes and weather-related occurrences, prompting talks about urban resilience. International organizations such as the International Organization for Standardization and the Standard for Sustainable and Resilient Infrastructure have created quantitative techniques for evaluating urban system resilience. Thus, urban resilience tools may be applied to any urban sector, such as water supply, waste management, electricity, communications, and transportation. There are four key ways to increase urban resilience: locational approach, structural approach, operational mitigation, and financial approach (Jha et al., 2013). The locational approach addresses risks associated with infrastructure development; the structural approach

is appropriate for existing infrastructure; operational mitigation entails alternative plans of action in the event of system failure; and the financial approach addresses specific short and long-term financial needs of urban sectors.

- **Mitigation Strategies**

  Climate change mitigation is a human action that aims to reduce greenhouse gas emissions or enhance sinks (Vijaya Venkata Raman et al., 2012). Urban mitigation strategies include reducing energy and material use for sustainable production and consumption, electrification for net-zero emissions, and improving carbon storage through urban green and blue infrastructure, which can provide numerous co-benefits while also promoting sustainable production and consumption (Ramaswami et al., 2023). Development may occur at numerous phases and dimensions, such as utilizing green areas for urban heat regulation, using local and creative construction materials, and enacting legislation that promotes more sustainable urban and natural ecosystems. Cities' major mitigation methods include efficient energy consumption, multi-modal transportation, renewable energy-powered transportation, land use planning, building direction, structure densification, mass transit, and non-motorized transportation (Das et al., 2022; and Telang et al., 2021). However, more substantial remedies entail alterations in societal behaviour and settlement patterns. Planning and urban design strategies may dramatically minimize vehicle trips by arranging human activity in compact communities, providing reliable transportation, and locating facilities within walking distance. A change in land use method alone can result in significant decrease in GHG emissions, with additional reductions possible through transit investment, fuel price, and parking costs (Houghton et al., 2012). Urban design may also claim characteristics associated with rural living, such as green infrastructure and local food production. Thus, development restrictions, transfer of development rights, mixed-use zoning, flexible parking, pedestrian zones, car-free zones, and building code modifications are all examples of regulatory methods that can manage urban growth and mitigate climate change.

- **Adaptation Strategies**

  Adaptation refers to the modifications made to ecological, social, or economic systems in response to climate change consequences, aiming to mitigate potential harm or capitalize on opportunities linked to climate change. In terms of adaptation, the United Nations Environment Assembly has identified Nature-Based Solutions (NBS) as a strategy that entails measures done to safeguard, maintain, restore, use, and manage ecosystems in a sustainable manner. Under NBS, urban green and blue infrastructure is critical for maintaining, managing, and restoring natural ecosystems while fostering human well-being and variety (Liu et al., 2021; and Lafortezza et al., 2018). The network aims to enhance community sustainability and local character in urban areas by incorporating street trees, green roofs, private gardens, pedestrian and cycle routes, agriculture area, water bodies, and green spaces etc. This strategy combines ecosystem-based approaches to address societal concerns like urbanization, climate change, and GHG emissions reduction (Hobbie & Grimm, 2020). It protects and increases carbon sinks, reducing emissions and cooling temperatures. The network of green and blue infrastructure creates a local cooling impact making the efforts of climate adaptation an essential part of urban development, contributing to the protection and reduction of GHG emissions.

URBAN PLANNING PRACTICES FOR CLIMATE CHANGE IN INDIAN CITIES

Cities are complex, linked socio-ecological systems. Therefore, adding resilience to the system would have a greater impact. India's cities are particularly vulnerable to climate change's effects, such as heat waves, changes in precipitation pattern and extreme weather. Resilience initiatives focus on integrating climate adaptation strategies into infrastructure development and urban planning, including green infrastructure, heat action plans, and flood management systems in metropolitan areas provide environmental, social, and economic advantages.

In Delhi, around 20,809 hectares, or 21% of the total

urban area, falls under the greens, which covers the Ridge, Biodiversity Parks, District Parks, City Parks, Community and Neighbourhood Parks. There are besides the greens in large campuses such as President's Estate, JNU, IARI, and Delhi University. The Miyawaki Technique was used by the Pimpri Chinchwad Municipal Corporation in Pune to create four urban woods at Shahu-nagar, Laxmi-nagar, and Punawale, totalling 7500 trees. This resulted in extremely thick urban forests that grow quickly in a small area for intense forestation and at a low cost.

The Kempegowda International Airport in Bangalore has vertical plantations and green roofs to enhance air quality, lessen the impacts of heat islands, and offer habitat for urban wildlife. The Terminal and boarding piers, which house more than two thousand plant species of Indian origin, are included in the Forest belt. Among the airport's most notable attributes is its biodiversity, which includes approximately 180 rare, endangered, and vulnerable species of Indian origin in addition to 600–800 year-old trees. The environment of the terminal includes more than 1200 different types of trees.

Chennai, which previously had over 474 wetland complexes, has lost more than 85% of its water bodies owing to rapid and unregulated urbanization. As part of its Smart Cities Initiative and attempts to mitigate disasters, the city has restored of its 200 wetlands. Pallikaranai wetland, one of south India's few surviving natural marshlands and a wintering habitat for many migratory species, including flamingos, has been restored for ecological and recreational reasons.

Since, Surat has seen an average temperature increase of 0.7 degrees Celsius over the past 30 years, the city's heat action plan focuses on strengthening heat resistance among vulnerable populations, such as slum residents and outdoor laborers. The strategy includes heat-health early warning systems, public awareness campaigns, and activities to strengthen the capacity of healthcare professionals, emergency responders, and community volunteers. Cooling centers and shaded spaces are created across the city to provide shade and amenities to vulnerable people. Oral rehydration solutions are supplied to disadvantaged groups to avoid dehydration and heat-related diseases.

Ahmedabad has set up a flood management system to reduce dangers during the monsoon season. The Sabarmati Riverfront Development Project consists of embankments, retaining walls, and walkways along the river to hold floodwaters and prevent flooding. Check dams and retention ponds upstream control water flow by capturing silt and surplus precipitation. The city features vast storm water drains and canals that move rainfall away from the streets. Green infrastructure components such as parks, gardens, and wetlands absorb surplus precipitation, promote soil infiltration, and increase the city's flood resistance.

CONCLUSION

Urban planning is a distinct profession integrating transportation, housing, climate change, energy, water, and urban design. Careful planning can help regulate urban expansion and density, impacting the size and shape of cities. Urban planners in the twenty-first century must work to develop sustainable urban settlements to serve society, the economy, and the environment. Urban planning for climate change is an interdisciplinary discipline encompassing strategies for fostering community resilience. It includes mitigation techniques, such as carbon-neutral development, and adaptation measures, such as nature-based solutions for managing future urban expansion without putting more people at risk from the repercussions of climate change. A climate-resilient urban future requires future building that achieves net-zero emissions criteria and responds to the most recent climate change research to reduce urban, regional, and coastal development hazards. Moreover, Carbon-neutral development, sustainable infrastructure, and innovative construction materials and practices are all critical components of urban planning for a more resilient urban future. However, the transformation of present urban planning must be community-based, use new techniques, and have the legislative support and resources to begin a dialog with vulnerable populations.

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LIGHTHOUSE PROJECTS : A JOURNEY FOR TRANSFORMATION OF CONSTRUCTION SECTOR

Dr. Shailesh Kr. Agrawal*, S. K. Gupta and Dalip Kumar*****

INTRODUCTION

Urban India is transforming at an unprecedented rate as regards urban renaissance is concerned. Besides, Atal mission for rejuvenation and urban transformation (AMRUT), there are other flagship programmes run by Ministry of Housing & Urban Affairs such as Smart Cities Mission, Swachh Bharat (Urban) Mission, Heritage City Development & Augmentation (HRIDAY) Scheme, Urban Transport & Pradhan Mantri Awas Yojana - Urban (PMAY-U). The PMAY-U has been the landmark in the annals of India history where it is dreamt to provide shelter security to one and all. It is one of the biggest missions ever thought of around the globe with the objective of providing 11.224 million houses. Under the mission, 11.863 million houses has been sanctioned, out of which 11.401 million houses are grounded and 8.002 million houses are completed/delivered to beneficiaries. More than 1.6 million houses are being constructed with emerging construction technologies in various States. It is high time to bring paradigm shift in the traditional construction practices through sustainable technologies which can speed up delivery of quality durable houses. The global pandemic COVID-19 have further accelerated disruption in the construction sector and modularization, standardization, off-site construction, introduction of new and lighter materials, safety and sustainability are going to be new normal in the sector.

The cast-in-place brick by brick construction and RCC beam-column construction are the things of past and are slow track construction practices. Also, it has been realized that these methodologies often offer time & cost overruns and are unsustainable in the long run. The world over, building construction has been shifted from site to the factory where building components partially or fully are manufactured and then transported to the site for their erection, assembly and finishing. This is known as typically precast or prefabricated construction where building components as a whole or in parts are cast in the factory. In addition, there are other options also such as replacing the wall by sandwich panels or creating a customized formwork for the building or manufacturing the entire three-dimensional building in the factory which can be pre-finished or printing the building layer by layer manufacturing at site. Most of these techniques are time-tested and proven and it is high time that we look at these global construction practices and adapt them to suit Indian conditions. These are fast track construction systems with much improved structural & functional performance, better durability, low life-cycle cost, resource-efficient, with minimum wastages, air & land pollution than the cast-in-situ RCC construction.

In order to have an integrated approach for comprehensive technical & financial evaluation of emerging and proven building materials & technologies, their standardization, developing specifications and code of practices, evolving necessary tendering process, capacity building and creating appropriate delivery mechanism, MoHUA set up a Technology Sub-Mission (TSM) under PMAY-U with the Mission statement as 'Sustainable Technological Solutions for Faster and Cost Effective Construction of Houses suiting to Geo-Climatic and Hazard Conditions of the Country'.

GLOBAL HOUSING TECHNOLOGY CHALLENGE - INDIA

To give it further impetus Ministry of Housing and Urban Affairs (MoHUA) conceptualized the Global Housing Technology Challenge – India (GHTC-India) as a platform with which a holistic eco-system can be facilitated so that appropriate technologies from around the world and relevant stakeholders can be catalysed towards effecting a technology transition in the housing and construction sectors of India. The challenges has three components (i) Conduct of a biennial Construction Technology India, Expo-cum-Conference, to provide a platform for all stakeholders to exchange

*Executive Director, Building Materials & Technology Promotion Council (BMTPC), MoHUA, Government of India, New Delhi,
** Dy. Chief (TDE&IC), BMTPC, New Delhi &
*** Sr. Field Officer (DC&E), BMTPC, New Delhi

knowledge and business (ii) Identifying Proven Demonstrable Technologies from across the world, and mainstreaming them through field level applications in Light House Projects (LHPs) across India, (iii) Promoting Potential Future Technologies through the establishment of Affordable Sustainable Housing Accelerators-India (ASHA-India) for incubation and accelerator support.

GHTC-India was launched by Minister of State (Independent Charge), MoHUA in January 2019 at New Delhi. Subsequently, Construction Technology India – 2019 (CTI-2019) : Expo-cum-Conference was held at Vigyan Bhawan, New Delhi during 02-03 March, 2019 to bring together multiple stakeholders involved in innovative and alternative housing technologies, for exchange of knowledge and business opportunities and master classes. The Expo was inaugurated by Prime Minister of India.

The applications were invited online globally from prospective technology providers. 54 alternate technologies were shortlisted based on the technical parameters and are being promoted as future technologies for the construction sector. These 54 technologies have been further categorized into 6 broad categories.

A. Precast Concrete Construction System - 3D Precast volumetric (4 Technologies)

B. Precast Concrete Construction System – Precast components assembled at site (8 Technologies)

C. Light Gauge Steel Structural System & Pre-engineered Steel Structural System (16 Technologies)

D. Prefabricated Sandwich Panel System (9 Technologies)

E. Monolithic Concrete Construction (9 Technologies)

F. Stay-in-Place Form work System (8 Technologies)

SIX LIGHT HOUSE PROJECTS UNDER GHTC-INDIA

The proven technologies are being showcased through six Light House Projects (LHPs) being built across six locations namely, Indore, Rajkot, Chennai, Ranchi, Agartala and Lucknow, using distinct technologies from each of the six broad categories. The objectives of the Light House Projects (LHPs) are:

a) Acquisition of innovative and proven housing technology knowhow by State/UTs.

b) Demonstrating and delivering ready to live houses with speed, economy and with better quality of construction in a sustainable manner.

c) To create mass awareness among stakeholders such as State/UT, Urban Local Bodies, technical professionals, builders, development agencies and others on alternate technologies being adopted in respective LHPs.

d) To serve as live laboratories for both faculty and students of IITs/ NITs/Engineering colleges/Planning and Architecture colleges, Builders, Professionals of Private and Public sectors.

e) Technical evaluation & documentation of alternate & innovative technology& mainstreaming of the technology.

f) Development of Schedule of Rates (SoRs) for selected proven technologies by CPWD and BMTPC.

The salient features of the LHPs are:

a) LHP, means a model housing project with approximate 1,000 houses built with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region. This will demonstrate and deliver ready to live houses with speed, economy and with better quality of construction in a sustainable manner.

b) The minimum size of houses constructed under LHP is in accordance with the prevailing guidelines of the Pradhan Mantri Awas Yojana (Urban).

c) Constructed housing under LHPs include onsite infrastructure development such as internal roads, pathways, common green area, boundary wall, water supply, sewerage, drainage, rain water harvesting, solar lighting, external electrification, etc.

d) Houses under LHP shave been designed keeping in view the dimensional

requirements laid down in National Building Code (NBC) 2016 with good aesthetics, proper ventilation, orientation, as required to suit the climatic conditions of the location and adequate storage space, etc.

e) Convergence with other existing centrally sponsored schemes and Missions such as Smart Cities, AMRUT, Swachh Bharat (U), National Urban Livelihood Mission (NULM), Ujjwalla, Ujala, Make in India have been ensured during the designing of LHPs at each site.

f) The structural details have been designed to meet the durability and safety requirements of applicable loads including earthquakes and cyclone and flood as applicable in accordance with the applicable Indian/ International standards.

g) Cluster design includes innovative system of water supply, drainage and rain water harvesting, renewable energy sources with special focus on solar energy.

h) The period of construction was 12 months from the date of handing over of sites to the successful bidder after all statutory approvals. Approvals have been accorded through a fast track process by the concerned State/UT Government.

The details of the LHPs are as under:

These LHPs are pilot housing projects which are paving the way for further adaption and use of these innovative technologies in the construction sector. The projects are showcasing construction of ready-to-live houses which are sustainable, cost-effective, resilient and built in much lesser time from the conventional cast-in-situ RCC framed construction.The Light House Projects at Chennai, Rajkot and Indore have been completed & handed over to the beneficiaries by the Hon'ble Prime Minister. The LHPs at Lucknow, Ranchi & Agartala are at advanced stage of completion.

These light house projects is acting as open live laboratories for different aspects of transfer of technologies to field applications. An online drive for Enrolment of TECHNOGRAHIS under GHTC-India: Light House Projects was launched by MoHUA. Technograhis are the Change Agents of innovative and sustainable technologies who will bring about technology transition in the construction sector for its adoption & replication in the country. They will act as Catalysts to Transform the Urban Landscape for New Urban India to fulfill the vision of Aatma Nirbhar Bharat. So far more than 35000 Technographis have registered for various LHPs. Technograhis are being exposed to the innovative construction technologies through on site activities to learn different phases of use of innovative technologies in LHPs as well as through offsite Workshops/ Webinars, Webcasting, Mentoring on Technical know-how/Module etc.

The details of innovative technologies used in six Light House Projects are as under:

S.No.	Location	DUs, Storeys	Technology
1.	Indore, MP	1024, S+8	Precast Sandwich Panel system (Precast RCC Columns & Beams, Hollow Core Slabs, EPS Cement Sandwich Panel walls)
2.	Rajkot, Gujarat	1144, S+13	Monolithic Concrete Construction (Tunnel Form)
3.	Chennai, Tamil Nadu	1152, G+5	Precast Concrete Construction – Precast components assembled at site
4.	Ranchi, Jharkhand	1008, G+8	Precast concrete construction – 3D Volumetric Construction
5.	Agartala, Tripura	1000, G+6	Light Gauge Steel Structural System & Pre-Engineered Steel Structural System
6.	Lucknow, UP	1040, S+13	Stay-in-Place Formwork System (Steel Structural System, composite decking floor & Stay-in-Place Formwork for walls)

LIGHT HOUSE PROJECT AT CHENNAI, TAMIL NADU

Project Brief:

- No. of Dwelling Units : 1152 Nos. (G+5)
- No. of Block / Tower : 12 Blocks
- Units in each Block / Tower : 96 Nos.
- Technology Used: Precast Concrete Construction System-Precast Components Assembled at Site

Technology Details:

- Precast building components (beams, columns, slabs, staircases, sunshades) are cast in casting yard near site
- Precast components erected sequentially to construct the entire building
- The joints between precast components (i.e. beam-column, beam-slab, column-foundation) are cast-in-situ for structural integrity and monolithic action
- The walls comprise of light weight and environment friendly Autoclaved Aerated Concrete (AAC) Block masonry.
- Internal services are pre planned in sync with precast components
- Minimum use of shuttering and scaffolding materials

PRECAST CONCRETE CONSTRUCTION SYSTEM-PRECAST COMPONENTS ASSEMBLED AT SITE

3S system incorporates precast dense reinforced cement concrete hollow core columns, structural RCC shear walls (as per design demand), T/L/ Rectangular shaped beams, stairs, floor/roof solid Precast RCC slabs, lintels, parapets and chajjas. AAC blocks are used for partition walls. Hollow core columns are erected above substructure, over which beams are integrated in the column notches followed by erection of slabs. Structural continuity and robustness is achieved through wet jointing using Dowel bars/ continuity reinforcement placed at connections and filling the in-situ self-compacting concrete in hollow cores of columns. All the connections and jointing of various structural framing components is accomplished through insitu self-compacting concrete/ micro concrete/ non-shrink grout as per design demand along with secured embedded reinforcement of appropriate diameter, length and configuration to ensure monolithic, continuous, resilient, ductile and durable behaviour (Fig-1 , 2 and 3).

3S Prefab Technology completely eliminates the use of timber and forest produce of any category. On the contrary, use of flyash and GGBS enhances the sustainability. The thermal and acoustic insulation provided by the AAC block masonry, facilitates reduction in energy towards maintaining comfort level temperature within enclosed habitat space. Also, considerable reduction in dead load is achieved due to use of form finish precast components & AAC material resulting into better performance under seismic loads.

All the structural components are pre-engineered and manufactured in factories / site factories with objective quality control resulting into dimensional accuracy, correctness in spacing of reinforcement, uniform protective cover, full maturity of components and assurance on design strength due to use of design mix concrete having minimal water-cement ratio which ultimately results into durable structure.

Essential Requirements : Precasting yard / factory set up is required with facilities such as Casting Yard, Computerised batching plant, Moulds, Transportation facility, Stacking yard for materials &

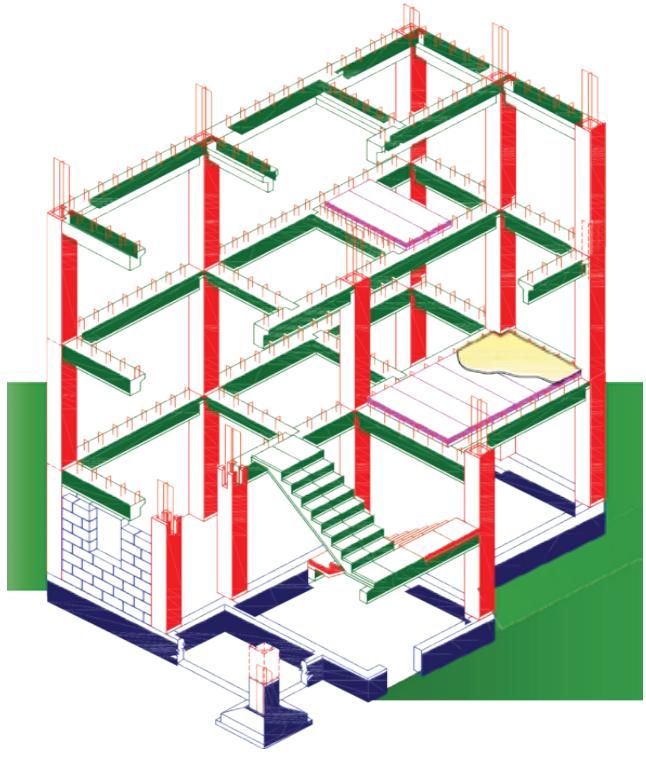

Fig.1: Structural configuration of 3S System

components, Lifting and loading facility, Laboratory to test raw material & finished products, Water tank of enough holding capacity as required for 2 – 3 days, Service road, etc. Utmost attention is required for process engineering before taking up any field work. Close co-ordination between design crew, field staff and quality crew is essential.

Fig.2: Beam – Column jointing

Fig.3: Completed Light House Project at Chennai

LIGHT HOUSE PROJECT AT RAJKOT, GUJARAT

Project Brief:

- No. of Dwelling Units : 1144 Nos. (S+13)
- No. of Block / Tower : 11 Blocks
- Units in each Block / Tower : 104 Nos.
- Technology Used: Monolithic Concrete Construction using Tunnel Formwork

Technology Details:

- Conventional RCC foundation is first laid upto plinth level
- Over the plinth, customized Tunnel formwork, made in the factory, is installed along with reinforcement cage
- Concrete is then poured into the Tunnel formwork to cast monolithically the entire module of the Unit.
- Next day, tunnel formwork is removed and taken to the next floor.
- During installation of the formwork for a floor, the service lines i.e. electrical, plumbing are also installed in thealready cut openings.
- Once the structure is finished, finishing items are installed.

MONOLITHIC CONCRETE CONSTRUCTION USING TUNNEL FORMWORK

Tunnel formwork is customized engineering formwork replacing conventional steel/plywood shuttering system. It is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day. The structure is divided into phases. Each phase consists of a section of the structure that will be cast in one day. The phasing is determined by the program and the amount of floor area that can be poured in one day. The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and slabs shall be poured in one single operation. The formwork is stripped the early morning next day and positioned for the subsequent phases (Fig. 4).

Fig. 4: Installation of Tunnel Formwork

The on-site implementation of 24 hour cycle is divided into following operations.

1. Stripping of the formwork from the previous day.
2. Positioning of the formwork for the current day's phase, with the installation of mechanical, electrical and plumbing services.
3. Installation of reinforcement in the walls and slabs.
4. Concreting and if necessary, the heating equipment.

The types of Formwork System are given below:

i. Modular Tunnel form

Tunnel forms are room size formworks that allow walls and floors to be caste in a single pour. With multiple forms, the entire floor of a building can be done in a single pour. Tunnel forms require sufficient space exterior to the building for the entire form to be slipped out and lifted up to the next level.

This Tunnel form consists of inverted L-shaped half tunnels (one vertical panel and one horizontal panel) joined together to create a tunnel. Articulated struts brace the horizontal and vertical panels. These struts enable the adjustment of the horizontal level of the slab and simplify the stripping of the formwork. The vertical panel is equipped with adjustable jacking devices and a triangular stability system. Both devices are on wheels.

A range of spans is possible by altering the additional horizontal infill panel's dimensions. Due to the distribution of the horizontal beams on the vertical plank, the formwork also cast staggers and offsets in the layout of the walls as well as differing wall thicknesses. The half-tunnels shall be equipped with back panels to cast perpendicular shear walls or corridor walls. Assembly and levelling devices ensure that the formwork surfaces are completely plumbed and levelled.

ii. Wallforms

Wallforms are temporary moulds in which concrete is poured in order to build a structure. Once the concrete is poured into the formwork and has set, the formwork is stripped to expose perfect finished concrete. These forms constitute a system approach for construction and are particularly suited to build structural walls, columns, bridge piers, culverts etc. This system adopts well to daily work-phase of both repetitive and non-repetitive tasks. The equipment used each day is productive and is reused in subsequent phases. The four daily operations which outlines the daily production cycle for wall form equipment are identical to those for Tunnel form equipment with the exception that it is solely used for casting concrete walls. The slabs are cast as a secondary phase. The existing equipment can be adapted on a day-to-day basis by the addition of standard elements and corner-wall formwork to take into account different wall configurations on site. All safety and stability devices shall be fully integrated into the standard version of Wallform equipment.

Fig.5: Tunnelform placing and casting of concrete

These Wallforms are tools specially designed to be used on specific buildings and structures. This vertical wallform panel is a multi-purpose formwork system. This system has been designed and developed to ensure that it is simple and quick to assemble and position the following:

Fig.6: Completed Light House Project at Rajkot

- A full range of standard dimensioned components
- Multiple combination of panels for simple adoption to specific configurations
- Basic standard equipment incorporates complete safety, circulation and stability equipment
- Caliper–device opposing Wallform packages are craned into position in one lift.

LIGHT HOUSE PROJECT AT INDORE, MADHYA PRADESH

Project Brief:

- No. of Dwelling Units : 1024 Nos. (S+8)
- No. of Block / Tower : 8 Blocks
- Units in each Block / Tower : 128 Nos.
- Technology Used: Prefabricated Sandwich Panel System with Pre-Engineered Steel Structural System

Technology Details:

- Over RCC foundation up to plinth level hot rolled steel columns and beams are erected, aligned and assembled toform structural skeleton frame
- Subsequently, deck slabs are laid with in-situ concrete screed for floors
- The factory-made Rising EPS Cement Panels are erected as wall panels. These are sandwich panelshaving light weight concrete core with thin cement fibre board as outer faces.
- While laying walls the service lines i.e. electrical, plumbing are also installed in the already cut openings
- Once the structure is finished, finishing items are installed.

PREFABRICATED SANDWICH PANEL SYSTEM WITH PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

These are lightweight composite wall, floor and roof sandwich panels made of thin fiber cement/ calcium silicate board as face covered boards and the core material is EPS granule balls, adhesive, cement, sand, flyash and other bonding materials in mortar form.

The core material in slurry state is pushed under pressure into preset molds. Once set, it shall be moved for curing and ready for use with RCC or steel support structure beams and columns. These panels are primarily used as walling material but can also be used as floor and roof panels. These are non-load bearing panels to be used with structural support frame only. However, if used in G+1 structure, these can be used as load bearing panels.

Size and Type of Panels

Size	:	Panels are normally produced in sizes and dimensions as given below:
Length	:	2440 mm (may be increased up to 3000 mm)
Width	:	610 mm (may be altered as per requirement but should not be too wide since handling of the panels become difficult)
Thickness	:	50-250 mm. Dimensions are shown in Fig. 1.

Panels are produced in 4 types i.e. Pole holes, Solid heart, Rod holes and Block hole. These four types of panels have different applications depending on the requirements e.g. Solid heart should be used as walling material in any type of construction and pole, rod and block hole may be used where different types of inserts are used like iron rods or wires for security etc.

In steel structure frame, panels can be fixed with either with steel clips or U type channels to hold the panels with the structure. Clips should be welded with the frame pillars or beams to hold the clips / U cannel firmly with the pillars /beans and floor. Then only the panels should be inserted into the U channels. There after PU glue should be applied to hold the panels firmly. The thickness of the panels shall determine the size of U channel. After installation of the panels in both the above systems, all gaps should be checked and filled with additives,

Fig. 7: Placement of Prefabricated Sandwich Panels in Steel Structure Frame

PU and cement mixers and later thin putty should be applied to give uniform smooth surface ready for paint.

Fig. 8: Completed Light House Project at Indore

LIGHT HOUSE PROJECT AT LUCKNOW, UTTAR PRADESH

Project Brief:

- No. of Dwelling Units : 1040 Nos. (S+13)
- No. of Block / Tower : 4 Blocks
- Units in each Block / Tower : A(494), B(130), C(208) & D(208)
- Technology Used: Stay in-place PVC Formwork with Pre-Engineered Steel Structural System

Technology Details:

- Over the RCC foundation up to plinth level factory-made hot rolled steel columns and beams are erected, alignedand assembled to form structural skeleton frame
- Subsequently, deck slabs are laid with in-situ concrete screed for floors
- The pre-finished PVC wall forms are then erected and filled with light weight concrete to construct walls
- While laying walls the service lines i.e. electrical, plumbing are also installed
- Once the structure is finished, finishing items are installed

STAY IN-PLACE PVC FORMWORK WITH PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

The rigid poly-vinyl chloride (PVC) based form work system serve as a permanent stay-in-place durable finished form-work for concrete walls. The extruded components slide and interlock together to create continuous formwork with the two faces of the wall connected together by continuous web members forming hollow rectangular components. The web members are punched with oval-shaped cores to allow easy flow of the poured concrete between the components. The hollow Novel Wall components are erected and filled with concrete, in situ, to provide a monolithic concrete wall with enhanced curing capacity due to water entrapment, as the polymer encasement

does not allow the concrete to dry prematurely with only the top surface of the wall being exposed to potential drying. The polymer encasement provides crack control vertically and horizontally for the concrete, and provides vertical tension reinforcement thus increasing the structural strength of the wall. The resulting system is unique and provides substantial advantages in terms of structural strength, durability enhancement, weather resistance, seismic resistance, design flexibility, and ease of construction. Steel dowels are necessary to anchor the wall to the concrete foundation.

This System is suitable for residential and commercial buildings of any height from low rise to high rise. In order to achieve speedier construction, strength and resource efficiency, the composite structure with Pre-Engineered Steel Structural System as structural members is being used in the present project.

Size of Panels

PVC Wall Forms have been developed in various cross-sectional sizes as per project requirement. The common sizes are 64mm, 126mm, 166mm & 206mm.

- N64 walls are erected individually and not preassembled, except for headers and sills.
- Pre-assembled walls sections are used for walls over 4300 mm (14') high

Fig. 9: Placement of PVC Wall Form Panels in Steel Structure Frame

- The height of walls made with the Formwork vary according to the requirement.
- N126 walls less than 4300 mm (14') high are erected individually except for walls of unique projects and for headers and sills.

Manufacturing Process in the Plant

The formwork Components are manufactured from extruded polyvinyl chloride (PVC). The extrusions consist of two layers, the substrate (inner) and Modifier (outer). The two layers are co- extruded during the manufacturing process to create a solid profile. The raw material is fed into the screw barrels of the extruders & heated in the barrels to molten form, where the temperature is electronically controlled. The extruded profile is cut to designed length, labelling of the components takes place in the coring, cutting, foaming or assembly areas, and the stay in place sections are ready to move for erection at site.

Fig.10: Completed buildings of Light House Project at Lucknow

LIGHT HOUSE PROJECT AT RANCHI, JHARKHAND

Project Brief:

- No. of Dwelling Units : 1008 Nos. (G+8)
- No. of Block / Tower : 7 Blocks
- Units in each Block / Tower : 144 Nos.
- Technology Used: Precast Concrete Construction System – 3D Volumetric

Technology Details:

- The building units are manufactured like Lego blocks in the casting yard in complete form including finishes
- These blocks are then transported, aligned and erected over the already laid RCC foundationto construct the entire structure
- These building units are also finished with services in the casting yard
- The building units are connected horizontally and vertically with proper jointing arrangements using base-plates, mechanical fasteners, nut bolts and concrete grouting.

PRECAST CONCRETE CONSTRUCTION SYSTEM – 3D VOLUMETRIC

An already established System for building construction in Europe, Singapore, Japan & Australia, this 3D Volumetric concrete construction is the modern method of building by which solid precast concrete structural modules like room, toilet, kitchen, bathroom, stairs etc. & any combination of these are cast monolithically in Plant or Casting yard in a controlled condition. These Modules termed as Magic Pods are transported, erected & installed using cranes and push-pull jacks and are integrated together in the form of complete building unit. Subject to the hoisting capacity, building of any height can be constructed using the technology.

Manufacturing process of the Building Modules/ Magic Pods

- 3D Steel moulds are created as suiting to various sizes of building Units
- High strength steel as per the structural design is placed inside 3D moulds
- Electrical and plumbing lines are set up. Block outs for doors and windows are also set up at the same time.
- The pods are cast into their final shape using high-performance concrete.
- Stringent quality checks is taken for each pod before they are packed for shipping, which ensures that the construction project adheres to strict quality standards.

Fig.11: Placement of Magic Pods

- The pods are then loaded and shipped. Care is taken to ensure that the shipping is done as per the sequence of erection at the site.

Construction & Installation Process

Sequential construction in the project here begins with keeping the designed foundation of the building ready, while manufacturing of precast concrete structural modules are taking place at the factory. Factory finished building units/modules are then installed at the site with the help of tower cranes. Gable end walls are positioned to terminate the sides of building. Pre stressed slabs are then installed as flooring elements. Rebar mesh is finally placed for structural screed thereby connecting all the elements together. Consecutive floors are built in similar manner to complete the structure.

Fig.12: Placement of Walls

LIGHT HOUSE PROJECT AT AGARTALA, TRIPURA

Project Brief:

- No. of Dwelling Units : 1000 Nos. (G+6)
- No. of Block / Tower : 7 Blocks
- Units in each Block / Tower : A (112), B(154), C(118), D(168), E(168), F(168) & G(112)
- Technology Used: Light Gauge Steel Framed (LGSF) System with Pre-engineered Steel Structural System

Technology Details:

- Over the RCC foundation up to plinth level hot rolled steel columns and beams are erected, aligned and assembledto form structural skeleton frame. Subsequently, deck slabs are laid with in-situ concrete screed for floors.
- The factory-made Light Gauge Steel Panels (cold formed steel panels) are then erected to form wall panel andconnected with the structural frame using self-driven metal screws.
- The Light Gauge wall panels are later covered with thin precast concrete panels (which are cast at site), and the hollow space between the panels is filled with light weight concrete.
- While laying walls, the service lines i.e. electrical, plumbing are also installed
- Once the structure is finished, finishing items are installed.

LIGHT GAUGE STEEL FRAMED (LGSF) SYSTEM WITH PRE-ENGINEERED STEEL STRUCTURAL SYSTEM

Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology is an innovative emerging building and construction technology using factory made Light Gauge Steel Framed Structure (LGSFS), light weight concrete and precast panels. The LGS frame is a "C" cross-section with built in notch, dimpling, slots, service holes etc. produced by computerized roll forming machine. These frames are assembled using metal screws to form into LGSF wall and roof structures of a building. Provisions for doors, windows, ventilators and other cutouts as required are incorporated in the LGSFS

The LGS frames are manufactured in a factory and assembled in to LGSF wall structures and then transported to the construction site and erected wall by wall on a pre-built concrete floor as per the floor plan of the building. Steel reinforced concrete panels of size 800mm X300mm X20mm thick are manufactured at factory and transported to site. These panels are fixed on either side of the LGSFS wall using self-drilling/tapping screws to act as outer and inner faces of the wall leaving a gap between them. This gap is then filled with light weight concrete using a special mixing and pumping machine. Electrical and plumbing pipes/conduits are provided in the service holes of the LGSFS before concreting is done. Self-compacting concrete is mixed and pumped into the gaps between two panels. The concrete flows and fills the gap and provides adequate cover to the LGS frames and joints. The concrete shall also adhere to the concrete panels. After curing, LGSFS with in-fill concrete and panels (LGSFS-ICP) forms a monolithic sandwich composite wall structure with thermal and sound insulation properties.

The roof structure of LGSFS-ICP building is

Fig.13: Placement of LGS frames in Steel Structure System

constructed using metal/plastic formwork system with steel reinforced concrete as per structural design. Standard procedures are employed to concrete the roof slab. After curing for 96 h, the formwork is demoulded and the wall and roof are putty finished. Door and window frames are fixed to the LGS frames and shutters fixed with necessary accessories. Finishing work such as laying floor tiles, fixing electrical and

Fig.14: Placement of Precast Concrete Panels filled with Light Weight Concrete in LGS frames

sanitary fixtures and painting is carried out using standard conventional methods.

After completion of ground floor, first, second and third floors of the building is constructed using the same procedure that of the ground floor. The staircase, chajja and parapet walls of the building are also constructed using LGSFS-ICP Technology.

CONCLUSION

The Ministry of Housing & Urban Affairs and BMTPC have been advocating use of fast track construction technologies for housing and it is more apt now since India is committed to climate change mitigation, reduction of carbon foot print, resource-efficient & environment-responsive clean technologies. Introduction of the identified construction systems will bring not only paradigm shift in construction sector but also bring cost-effective systems, better environment, enhanced building marketability, reduced liability, improved health & productivity, low life cycle cost. Already, a sizeable number of companies have set up plants for manufacturing customized building components in India. It is required to give them little push/incentive and create an enabling eco-system which facilitates use of these systems through our procurement methodologies. The day is not far when India will start manufacturing buildings.

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ISSUES & OPTIONS FOR RATIONALISING URBAN PLANNING & DEVELOPMENT

Jit Kumar Gupta*

Abstract

Census, 2011, recorded 31.1 % of Indian population living in urban India, contributing 63% of India's GDP. As per projections made by 2030, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP. India has already emerged as the most populated country globally in the year 2023, with population standing at 1.4 billion. Considering the existing rate of demographic growth, India will house 1.6 billion people by the year 2050 with 800 million people living in urban areas. Known as engines of growth and development, cities are involved in generating wealth, promoting economy and prosperity. Despite having distinct advantages, cities are globally known for dualities & contradictions besides positivity and negativities. In order to launch India on the fast trajectory of rapid growth and development, it will be critical to remove all prevailing negativities and build on available positivities of urban areas. In search for appropriate solutions, to make cities; more productive, more efficient, better places to live, have better quality of life and achieve the goal defined in SDG 11; paper looks at the options of; redefining urban planning; promoting affordable housing; empowering ULBs; making available adequate infrastructures; leveraging technologies; empowering poor; involving communities, etc.

INTRODUCTION

India is urbanising massively due to increase in population, migration of people from rural to urban areas; large investments being made in housing, urban transport, water supply, power-related infrastructures and promoting missions related to smart cities, housing for all etc. Majority of increase in population is getting localised in the existing towns/cities, leading to increase in density and high degree of congestion. Looking at the prevalent trends, urban growth is expected to continue, led by urban pull and poverty pushing people to urban areas. During last 100 years, India witnessed, urbanization level going up 3 times; urban settlements growing merely 4 times; total population multiplying 5 times; urban population increasing 15 times and rural population increasing merely 3.5 times. Massive shift of population to urban areas, is not simply a shift of demographics but places cities/towns at the centre/core of India's development. As per Smart City Mission; nearly 31% of India's current population living in urban areas contributed 63% of India's GDP (Census 2011). With increasing urbanization, urban areas are expected to house 40% of India's population and contribute 75% of India's GDP by 2030. By 2050, India will have a human count of 1.6 billion with 800 million people living in urban areas, as compared to 377 million living in the year 2011.

**Founder Director, College of Architecture, IET Bhaddal, Chandigarh*

ISSUES AND OPTIONS

Being most populated country and having large share of urban population, urban India will face large number of challenges and offer distinct opportunities for the nation, in years to come. Challenges posed by massive urbanisation can be enumerated in terms of; haphazard and unplanned development; urban sprawl; growing vulnerability to climate change; increasing shortage of housing; inadequate services and amenities; mushrooming of slums; increasing migration; growing poverty; problems related to mobility etc. As against numerous challenges, opportunities offered by urban India, will include; making India third largest global economy; creating large scale employment; eliminating poverty; providing best of infrastructure and services; making human living more qualitative and meeting the national goal of housing for all. However, for overcoming challenges and making opportunities a distinct reality, urban India will have to be planned, designed, developed, managed and governed differently and distinctly. Few of the challenges faced by Urban India and options, that can be leveraged to overcome these challenges, have been enumerated below.

- **Promoting Planned Development:** Planning remains central to orderly growth and development of cities. Majority of cities in India do not have any planning framework in the shape of Master Plans/Development Plans to guide their present and future growth. As per report of Niti Ayog', 65% of the 7,933 urban settlements in India do not have any master plans, which regulate use of land. And promote planned development. Even in case of cities where master plans are available, non-implementation of master plans has led to haphazard constructions, aggravating problems like traffic congestion, pollution, poverty and flooding. Majority of cities in India are growing in an unplanned and haphazard manner. In addition, majority of plans prepared have also become outdated and not revised, reviewed and redefined and accordingly do not reflect the concern of urban local dwellers. Metropolitan Area Development Plans and District Development Plans, as mandated by 74th amendment Act, are conspicuous by their absence. Lack of human and financial resource for undertaking planning,lower capacity of state planning departments and lack of political will and commitment; are the major reasons for the existing scenario/ regime of unplanned development prevailing in urban India.

  Looking critically and historically, it can be observed that in pastmajority of national and state government policies were primarily biased against urban sector with approach focused on restricting the growth of urban centers, minimizing migration and encouraging people to stay in the rural areas. Despite restrictive policies, urban centers are growing at a phenomenal pace. This calls for changing our priorities and strategies towards urban areas. Looking at the role, relevance and importance of urban areas in promoting prosperity and productivity, instead of restricting their growth, policy should aim at allowing these centers to grow at their natural pace with states acting as facilitators, ensuring that all urban dwellers have access to basic minimum facilities, required for having an appropriate level of quality of life. Globally, it has been accepted that planned urban development always contribute positively, whereas unplanned development ushers an era of chaos and poverty. Launching numerous urban focused Mission and Yojnas, involving promoting planned development, creating affordable housing, making provision of open spaces, providing basic amenities/services, providing good governance, leveraging technologies, promoting green transportation and making cities clean and greenhave already ushered an era of rapid growth and development in cities like Chandigarh, Indore, Pune, Bhubaneshwar, Vishakhapatnam, Nagpur, etc. However, programs need to cover all urban centres in the nation in years to come to usher an era of planned growth.

- **Making Cities Compact:** Urban sprawl and uncontrolled expansion, both in population and geographical area of rapidly growing cities, is the root cause of majority of urban related problems. Limited economic resources available with majority of cities make them incapable of dealing with the problems created by large physical size, making available adequate services, rationalizing mobility and encroaching upon precious agricultural land. Accordingly, in addition to promoting planned development, it will be critical to ensure that urban growth is made compact in order to make cities sustainable and least consumers of energy, resources and land, compact city, offers best option of urban development. Globally compact city has been accepted as one of the best options, to overcome major ills facing urban areas. India, being one of most land stressed nation, has no option but to promote compact city as the preferred typology of urban development.

- **Making Housing for All-Distinct Reality:** Unchecked, unplanned and haphazard growth of urban areas has genesis in the mushroom growth and spread of slums and squatter settlements which present a striking feature in the ecological structure of Indian cities, especially of metropolitan centres. Extreme unhygienic living conditions, impoverished population, overflowing excreta, temporary structures, lack of basic amenities, remain the distinct features of urban slums. Housing one sixth of urban population, slums pose enormous challenge to sustainable development of urban India. In addition,

over-crowding invariably leads to a chronic problem of shortage of houses in urban areas. This problem is specifically more acute in large urban areas. Large influx of unemployed or under employed immigrants, with little financial capacity and resources invariably lead to inability of migrants to find affordable place to live, when they enter cities/towns from the surrounding areas. Factors responsible for housing problems faced by the urban people include; high cost of urban land; shortage of developed land; shortage of financial resources; lack of employment; large vacant urban land etc. Technical committee set up by Governmnet of India estimated housing shortage to be of the order of 24.71 million dwelling units at the end of 12th Five Year Plan, with 99% shortage in EWS & LIG housing. Considering the fact that majority of housing shortage was concentrated in low-income categories, accordingly Government of India launched the mission, Housing for All in the year 2015 to increase the supply of housing for lower bracket of economy. As per portal of GOI, 118.63 lakh houses have been sanctioned and 80.02 lakh completed on Feb 8, 2024. However, options to overcome the perpetual housing shortage should include; making land market more efficient, involving private sector; improving construction technologies; rationalising government charges/fees; making housing cost-effective; creating large stock of rental housing; making available more financial resources at lower cost; adopting project based approach; treating affordable housing as a volume game; completing projects on time bound basis; providing single window for time bound approval; involving beneficiaries and changing approach from creating ownership of shelter to providing shelter for all.

- **Promoting Good Urban Governance:** Critically and objectively looking at the existing urban scenario, it can be concluded that urban growth per-se is not bad. It is the demand which outpaces the institutional, administrative and financial capacity to cope with it, effectively and efficiently. Low capacity of urban India, to meet the urban challenges, has primarily led to cities growing in unplanned and irrational manner. Despite the fact that urban local bodies have long history spanning over three centuries with Madras Municipal Corporation being established in 1688, not much headway has been made to empower the urban local bodies to grow in terms of their capacity to effectively discharge their functions, duties, responsibilities within local areas. The basic tenor, character and structure of local bodies has remained unchanged despite dramatic change in the complexion of their duties and people's aspirations. Financial base of ULB's has been systematically eroded, by taking away most of the productive sources of revenue, diluting/marginalizing their role in urban development. In Indian context, urban centres are being governed by proxy because of excessive controls exercised by state governments over local bodies and large number of state agencies operating at local level, duplicating the work of urban local bodies. 74th Constitutional Amendment Act, 1992, has defined framework for providing authority, resources, duties and responsibility to local bodies; in order to enable them to act and perform like governments in their own right at local level. However, amendments made for empowering urban local bodies remain on paper and are being followed only in letters and not in spirits. Local governments, being closest to the people at local level, need to be adequately strengthened and empowered in terms of their administrative, fiscal, technical and political capacities to enable them to emerge as governments in their right and discharge all their obligations of managing urban centres with effectiveness and efficiency. States must hand-hold the urban local bodies by providing adequate resources-both financial and managerial, in order to enable them to reform and perform as governments in their own right. It needs to be understood and appreciated that; empowering urban local bodies remains the best option to make cities most efficient and vibrant because cities cannot be run and managed by proxy, applying remote control. Cities like Ahmedabad, Surat, Pune, Indore, Nagpur, Bhopal, Lucknow etc. have clearly demonstrated the efficacy and efficiency of Municipal Corporations in making cities vibrant, clean, green and efficient.

- **Mobility:** According to the World Health Organization (WHO), 10 percent of the world's road fatalities (130,000), traffic crashes every minute, and a life is lost every 3.7 minutes occur in India. Accidents have significant negative impact on the nation's economy, costing nearly 3 percent of its GDP. Withever increasing traffic bottlenecks and congestion, almost all urban centres are suffering from transportation problems. Transport related problems invariably increase and become more complex as the town grows in size. Travel and traffic are known as the worst gifts of urbanization. Large number of people are travelling and are getting trapped in the traffic jams on daily basis, caused by large number of vehicles and roads having limited capacity. Increasing travel demand and reduced speed, invariably leads to making cities less productive, more inefficient and highly polluted. Heterogeneity of traffic; large number of individual cars on the roads; lack of mass transportation; poor road geometry; lack of discipline; low level of awareness about traffic rules and lack of respect for the laws; remain the major reasons for traffic blues in the urban areas. In order to rationalize the traffic within urban areas, there is need to change approach to traffic and transport planning- from planning for vehicles to planning for people; and promoting accessibility not mobility. Supplementing these principles with prioritisng pedestrianization and cycling, as against individual cars besides making public transport more effective and efficient, will help in rationalizing the traffic in cities. In addition, city planning needs to be redefined by using Transit Oriented Development (TOD) and mixed lands-use, as options in urban planning. Metropolises like Delhi, Mumbai, Ahmedabad and Chennai have survived only due to innovative options of mass transportation put in place in these cities.
- **Providing Universal Access to Infrastructures:** Quality of life remains largely contingent upon the availability of adequate and quality infrastructures. Looking at the existing scenario, infrastructure in urban areas presents a grim picture. In majority of cases, cities suffer from the malaise of; inadequate infrastructures and services; mismanaged garbage; unauthorized constructions and unplanned development and pot-holes dominating the road network. Quality of life continues to be poor for majority of urban residents with city functioning getting adversely impacted. Thus, it becomes essential that, for making urban areas better places to live and for ensuring their productivity, providing urban infrastructures, on prescribed norms and standards to all residents, need to be given priority on the local agenda. However, it needs to be understood and appreciated that providing and maintaining infrastructures remains highly cost-intensive. High Powered Committee, set up by Government of India on Urban Infrastructures; assessed capital investment of Rs 39.5 lakh crores besides an expenditure of Rs 19.5 lakh crores for maintaining the eight selected urban infrastructures for the period 2010-2030. India has also brought out latest Infrastructure Report in the year 2023 for promoting economy and productivity. Looking at the cost implications, best option to provide adequate infrastructures in any area shall be to promote planned development; which will not only ensure making provision of internal development but will also generate resources for funding and providing space for external/ city level infrastructures. However, it needs to be understood that infrastructures must be built involving latest technologies and should have low operational cost for remaining cost-effective over its entire life-cycle. Planned development is known to help in loading the cost of infrastructure on the developed land and recover it through the cost charged for developed land. As a matter of principle adequate and appropriate level of physical and social infrastructures must be made available to even poorest of the poor citizen to lead a dignifies living. Cities like Chandigarh, Gurgaon, Indore, Jaipur, Ahmedabad have clearly demonstrated how cities can manage provision of quality infrastructures and services in urban areas.
- **Urban Pollution:** With rapid pace of urbanisation, industries and transport systems grow rather out of proportion. These developments are primarily responsible for creating favourable options for promoting pollution in urban environment. Smog and smoke have become integral part of urban

environment and urban living. Capital city of Delhi is known for high degree of pollution particularly during winters, when visibility gets reduced and air pollution hits badly the people and operation of cities. With ever increasing pollution, vulnerability to man-made and natural disasters is increasing. Pandemic Covid-19, accounted for 90% cases in urban areas, adversely impacted the functioning, operation, economy, employment and livability in urban sector, as compared to rural areas. According to UNDP 70 % of Indian population is at risk to floods and 60% susceptible to earthquakes. The risks are higher in urban areas owing to density and overcrowding. In order to improve quality of life in urban areas, it will be important that all sources causing pollution are identified and appropriate options put in place, to eliminate/manage/mitigate such sources of air and land pollution. Making industries run on green electricity rather than coal/fossil fuel; relocating polluting industries; separating residential areas from industries by a green belt and appropriately locating industries based on the wind flow etc., will go a long way in minimising pollution caused by industries. Promoting green transport; increasing number of trees and green spaces are known to be best options to minimise pollutants, clean air, generate oxygen and absorb CO_2. Accordingly, it will be appropriate that green spaces are provided as integral part of urban planning process to make cities happy and healthy.

- **Empowering Urban Poor:** Poverty, as a human problem, remains the greatest curse ever perpetuated on humanity due to its adverse impact of marginalizing, muting and diluting human living. Majority of urban ills related to housing; overcrowding, unplanned development; informal living; street vending; deficient infrastructures, unemployment, begging etc. has its genesis in the poverty. Roughly one-third of urban population today lives below the poverty line. The most demanding of the urban challenges, unquestionably is the challenge posed by poverty; challenge of reducing exploitation, relieving misery and creating more humane condition for urban poor. Prime reason for poverty is the exclusion of poor from the planning process. In order to overcome challenges posed by poverty, it will be critical to empower poor by making them integral part of city planning. This will help poor in getting space for living and working in urban area, opportunities for getting skilled for undertaking gainful employment and become integral part of urban community. City planning must focus on empowering poor to make cities better place to live and work. National Urban Livelihood Mission, launched by Government of India, is a step to empower urban poor.
- **Involving Communities:** People participation remains critical for rational planning and orderly development of cities and towns. People need to actively participate in the urban governance and reforms. However, in the Indian context, people participation remains marginalized and all planning and development projects are prepared within the closed walls of offices without involving people/communities in the planning and development process. This has done more damage than good to the urban growth and has been considered as prime reason for promoting unplanned/unregulated development of cities. Accordingly, active people participation shall hold key to promote planned development and make urban development people centric.
- **Limited use of Technology in Planning and Managing Cities:** In the art and science of planning, designing and managing cities, use of technology including use of IT/IT enabled services have been found to be minimal. Most of planning and development related functions are performed manually. Technology holds distinct advantages and has shown its potential in all facets of city planning, monitoring delivery of services, making services universally accessible, rationalizing transportation, managing garbage disposal, water management, street lighting etc. Major challenges facing cities can be effectively met by leveraging innovative technologies. Understanding the role and importance, technology has been embedded as integral part of Smart City Mission under which Control Centres have been set up to monitor number of essential services in cities.
- Niti Ayog in its recent document, Reforms

in Urban Planning Capacity in India-Final Report; September 2021; has highlighted major challenges facing Urban India, in terms of :

- Absence of statutory Master Plans for majority of urban centres
- Underutilization of Urban Land
- Large proportion of urban population living in Slums
- Increasing Risk of Water Scarcity
- Inadequate focus in City Planning on Disaster Mitigation
- Increasing pressures on Coastal Habitation
- Lack of Multi-Disciplinary and Multi-Sectoral approach in Urban Planning

CONCLUSION

Globally, cities are known to be major propellers of global warming, climate change, generators of large carbon footprints, consumers of resources and generators of waste. Accelerated urbanization adversely impact climate; by creating demand for large mobility, increased commercial/industrial activities, creating large built space, higher energy consumption and use of natural resources. In order to mitigate the global warming, process of urbanization has to be made more rational and sustainable by using state of art technologies and by involving communities. 'Combined with modern technology, better urban planning can solve many problems that cities are facing, so as to lead them to prosperity' (UN-Habitat). Accordingly, it becomes important that cities are, properly planned, effectively developed and rationally governed. by promoting state of art planning; making cities compact; rationalizing mobility; empowering urban local bodies; empowering poor and leveraging technology. Rational and planned development of urban centres can usher an era of balanced growth besides realizing the goal / targets/agenda embedded in SDG 11- Making Cities and Communities- safe, resilient, inclusive and sustainable.

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CLIMATE CHANGE & DRAINAGE CHALLENGE IN URBAN PLANNING & DEVELOPMENT

Dr. K. M. Soni*

Abstract

Drainage has become a critical issue in urban planning and infrastructure globally but particularly in India due to local continuous weather and climate change hence urban planners have to include drainage system as a main issue in urban planning. Urban planners and engineers involved in urban planning and implementation of services need to take immediate traditional and innovative measures to prevent stagnation of water due to rains.

Buildings and other infrastructure like roads, bridges, culverts are designed considering past flood levels but need to be designed considering past and estimated futuristic flood levels.

As submergence is likely to happen in low lying areas of coastal regions due to changed weather conditions and climate change, immediate plan needs to be prepared for prevention of flooding in coastal areas. Thus, there is a need of integrated approach for urban planning considering critical conditions.

INTRODUCTION

Climate is the weather of a specific region averaged over a long period of time while weather refers to short term atmospheric conditions. As per the definition given by UN, climate change refers to long-term shifts in temperatures and weather patterns. Such shifts can be natural, due to changes in the sun's activity or large volcanic eruptions.

Climate change is primarily said to be due to the burning of fossil fuels like coal, oil and gas generating greenhouse gas emissions (GHGs) that act like a blanket wrapped around the Earth trapping the sun's heat and raising temperatures. Main GHGs responsible for the climate change are carbon dioxide and methane, coming from using petrol/diesel (gasoline) for driving vehicles or burning coal for heating a building, generating electric power or for any other purpose or due to land clearance and cutting down forests. Methane comes from agriculture, oil and gas operations. Therefore, energy, industry, transport, buildings, agriculture and land use are among the main sectors causing greenhouse gases and urban planning has to consider all of them necessarily even if agriculture may not be included but green spaces and horticulture may be. Interestingly, climate change is the result of urbanization which required considerable energy and transport. Since urbanization cannot be stopped, researchers are finding out the ways and means to switch over to the energy sources which may not generate GHGs and vehicles running on non-generating GHG resources.

Climate change has become a global issue and the nations have already started taking action to control it but globally weather change has entered silently and posing a great challenge to urban planners and engineers than the climate change due to severe and frequent flooding in urban areas and landslides, collapse of houses, bridges, roads, highways, electrical and tele-communication lines in hilly regions resulting into wastage of crores of rupees.

RESPONSIBILITY OF CLIMATE CHANGE

The scientists agree that humans are responsible for climate change thus for global warming, being the users for GHGs so they have shifted their attention on the sources generating GHGs. Though, climate change is not a new phenomenon and has been continuing for the ages, it has increased manifold during the last 200 years due to overexploitation of natural resources. In 1804, human population was 1000 million while during 2023 is 8045 million. The world population needs

*Former ADG, CPWD, New Delhi

8 times more habitats i.e. land for their living, land for agriculture and infrastructure development works around the world hence large amount of methane and carbon dioxide is generated. With industrialization, need was converted into unsustainable desire and greed. Thus, actually large population and its multiple and large requirements by way of need or greed including energy has led to the situation of weather and climate change due to which urban planners all over the world are facing problems of floods and inadequate drainage.

MEASURES BEING TAKEN TO REVERSE THE PHENOMENON OF CLIMATE CHANGE

Scientists and policy makers are now afraid of the consequences of the climate change and want to reverse the phenomenon of the climate change or at least control it. World leaders made discussions and decided to control it during UN Framework Convention on Climate Change and Paris agreement. However, it is to be understood that the reversible climate change may not bean easy phenomenon due to increasing population, more and more human needs, greed and high energy-based lifestyle. Also, it is almost impossible to control population, human needs and greed hence scientists are doing their job by way of finding out ways to switch over to non-conventional sources of power generation while urban planners are involved to resolve the issue of planning the services for ever growing population. The world leaders have also understood it and thus taken decision to reverse or at least control the climate change by way of switching to energy generation from fossil fuels to no conventional energy resources like solar, wind, water etc. The targets have been recommended to switch over to net zero emissions by 2050 however few countries aimed at to 2070. It is also aimed to cut emissions GHGs to half by 2030 to keep global warming below 1.5°C. At present, scientists are only concerned about lowering the temperature of Earth without having much concern of change of weather conditions of local regions as such are to be taken care by urban planners.

UN Secretary-General outlines five critical actions the world needs to prioritize to speed up and shift to renewable energy systems and commented its need as, "because without renewables, there can be no future." Thus, renewable energy has been considered clean, accessible, affordable, sustainable, and reliable as renewable energy sources are said to be available in abundance around us provided by the sun, wind, water, waste. But, the effect of unsustainable use or exploitation of solar energy and wind is also not known and may be that over exploitation of solar and wind energy alters regional weather conditions and lead to abrupt change of weather conditions. It appears that heat from sun and rains are directly related. Deserts have been very hot traditionally having almost no or very little rains. Now with installations of the solar panels, the heat is going to be trapped and as such temperature conditions are going to be altered due to change in atmospheric temperature of local areas. Similarly, wind mills are going to control the wind speed hence the lower wind speed is going to change the temperature conditions. Change of heat and temperature conditions are going to change the weather conditions locally affecting weather and even climate of many places if harnessed in unsustainable manner. It is possible that deserts may experience rains and tropical rain areas may result into desert like conditions even thought by the urban planners. Interestingly, urban planners have started planning solar panels almost in every building and slowly solar panels are being provided on vehicles, trains, roads, canals and open spaces. Such provision appears to be unsustainable without study of its impact on weather and climate. Any un-sustained exploitation of solar and wind may affect human life adversely.

ESSENTIAL ELEMENTS OF URBAN INFRASTRUCTURE

Urban planners consider various factors affecting urban life and include the following;

- Mobility and transport
- Roads, highways, and other communication systems
- Water supply and sanitation
- Waste generation, disposal and its recycling
- Electricity generation, transmission and use
- Telecommunications

- Education, health and well being of the residents
- Development of public places and green areas, pollution and environment
- Public offices and housing
- Migration and provisions for future expansion
- Economy
- Sustainability

All such infrastructure needs construction materials, fuel, electricity and water in their development process and thereafter during their operation and maintenance. It is observed that consumption of electricity and fuel goes up as quality of life and economy improve. Also, mobility, services and economy all have dependency on quality infrastructure to be made available on 24x7 basis hence urban infrastructure has to be sustainable for future requirements of the effects of climate change simultaneously sustainable to all weather conditions. Considering, requirements of all-weather requirements, urban drainage has become most critical.

URBAN DRAINAGE AND URBAN PLANNING

Urban planning is always made futuristic hence assessment of the future requirements becomes a challenge for the planners whether brownfield or greenfield though it becomes more difficult in brownfield development i.e. in existing urban areas. Migration of working people particularly lower income group makes urban planning further difficult resulting into growth of slums and non-engineered, unplanned and unsafe structures. Such a development also is in conflict with environment resulting into traffic congestion, difficulty in laying of essential services, pollution, poor air quality, and mix land use even though may not be permitted. Many times, required norms of laying essential services like water supply, sewer lines, solid waste removal and drainage are difficult to be followed in such cases leading to unhygienic conditions. Political and social compulsion make it very difficult to demolish such structures. Therefore, such un-planned and unauthorised infrastructure development has high risk during flooding and natural disasters like earthquakes. In planned areas also, change of FAR/FSI leads to overloading of services, particularly in brownfield areas. This has resulted into poor drainage infrastructure in almost all urban areas.

As seen from last few years, flooding occurs mainly due to the following;

i. Torrential rains
ii. Cloud bursts
iii. Inadequate urban drainage
iv. Poor drainage management
v. Failure or overloading of water retaining structures like dams and barrages

Torrential rains and cloud bursts have caused severe damage to infrastructure in hilly areas as well as other places said to be due to climate change. Also, unplanned, non-engineered development, poor quality construction and extensive destabilization of hills have aggravated the problem. Failure or overloading of water retaining structures due to cloud bursts and sudden water inflow may also be due to climate change. Drainage system in urban areas has failed miserably in most of the cities even due to normal rains as may be seen from the photographs given in Fig. 1 to 10.

The reasons of poor or inadequate drainage can be listed as follows:

i. Poor or inadequate design of drainage system
ii. Linking of drainage with existing inadequate drainage system without augmentation
iii. Increase of impervious surfaces
iv. Designing of individual campuses and connecting to existing system, not coping with integrated design
v. Approval of drainage system without technical considerations by the local bodies
vi. Unauthorized construction and encroachment
vii. Enhancing FAR/FSI without augmentation of drainage system
viii. Construction of roads, bridges, flyovers and other paved areas without drainage system
ix. Poor maintenance of drainage system
x. Linking drainage system with sewerage system
xi. Silting and filling of urban lakes and ponds
xii. Inadequate funds
xiii. Postponement of augmentation of drainage infrastructure due to low priority
xiv. Floods

Fig. 1: Flooding in Delhi

Fig. 2: Flooding in Patna

Fig. 3: Flooding in Lucknow

Fig. 4: Flooding in Chennai

Fig. 5: Flooding in Ahmedabad

Fig. 6: Flooding in Bengaluru

Fig. 7: Flooding in Gurugram

Fig. 8: Flooding in Kolkata

Fig. 9: Flooding in Mumbai

Fig. 10: Flooding in Hyderabad

xv. Backflow from the rivers due to silting of rivers

xvi. Unsustainable exploitation of solar and wind power

Drainage is not given due importance by most of the executing agencies and connect their drainage system to the existing drainage system without going into details of its capacity. Though local bodies are responsible to accord approval, the engineers involved in according the approval are either forced to accord the approval on completion of infrastructure or they are not very serious in working out the capacity.

The maintenance of existing drainage system is also not generally carried out properly and gets silted at many places due to which water gets stagnated. This situation leads to mixing of storm water into sewer system and sewer lines also get flooded resulting into sewage mixing with drainage. Whatever may be the reason as listed above, drainage system has failed in many cities and has resulted into highly unhygienic conditions.

Flooding in most of the cities during rains indicates that the drainage has become inadequate. Now, this is the high time to consider all the factors listed above in integrated manner as flooding results into direct and indirect loss of manpower, lives, properties, and high repair cost of damaged infrastructure. Urban planning of drainage system has to be taken up in integrated manner by all the agencies involved in planning, construction and maintenance. A separate agency may be required at state or national level to look into it seriously. Till the expert and exclusive agency is not in place, the following may be required;

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

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

iii. Concept of drainage infrastructure followed in urban areas like streams, rivers, lake and baolies should be rejuvenated and even reconstructed.

iv. Planning policy should include less impervious surfaces, say not more than 30% of open area in a campus.

v. Desilting should be taken up in all rivers and lakes timely to make them fully functional.

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

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

viii. Urban drainage infrastructure should be taken up on mission mode by Government of India with the participation of state governments through Special Purpose Vehicles.

ix. A separate specialized programme should be developed for flood protection and drainage system and all architects and engineers involved in the planning should be trained in the same.

EFFECTS OF WATER STAGNATION

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

ii. The high flood level (HFL) should not only be based on past data but also considering estimated HFL in future due to floods.

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

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

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

CONCLUSION

The following conclusions are made;

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

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

iii. All bridges should be designed considering HFL higher than considered on past basis.

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

v. Laws should be enacted for removal of encroachment on the drainage system.

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

vii. Plan should be prepared and works taken up in low lying areas of coastal regions for preventing flooding and submergence.

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SMART CONSTRUCTION: ADVANCEMENT THROUGH PRECAST & 3D PRINTED WALL PANELS

Yeturi Pramod Kumar Reddy*, M. Anil Kumar, Dr. Sri Kalyana Rama J*** & Dr. Visalakshi Talakokula******

Abstract

Global attention is required to adopt new technologies in the construction sector to boost productivity and provide sustainable results. Manufacturers have developed innovative tools and technologies to evolve the need to achieve greater quality and higher efficiency. Sandwich panels and 3D concrete printing (3DCP) have emerged as key players in modern precast construction, with sandwich panels incorporating the concept of "lightweight design" while 3DCP involves layer-wise material deposition. Additionally, Sandwich panels possess good insulation offering other benefits, including energy consumption, minimized environmental impact, and comfort leading to an increasing emphasis on sustainability by using sustainable materials to create eco-friendly products. Optimizing the design and manufacturing process is essential to ensure strength, durability, and ease of installation compared to conventional methods. This paper discusses the applications and benefits of lightweight modular sandwich panels and the potential approaches to adopting 3D printing technology into their production.

INTRODUCTION

- **Prefabrication Components**

  Precast and prefabrication elements reduce material failures, speed up the construction, enhance quality, consistency, homogeneity, buildability, and supervised work under a controlled environment. Precast systems include planter boxes, floors, staircases, facade walls, partition walls, slabs, beams, and columns. They also include architectural components.

  Compared to cast-in-situ construction, prefabrication technology involves higher levels of precision with very limited tolerance. A higher level of precision needs to be attained early in the design process. Prefabrication can be done with Expanded Polystyrene (EPS) modular panels, 3D modular construction, columns, beams, and slabs. As they are robust, lightweight, and have excellent insulating qualities, high strength-to-weight ratio EPS sandwich panels and modular panels are becoming more popular in mass housing. Further more, the researchers observed that the size of EPS beads has a very noticeable influence on strength of concrete. Below, the technology is described in terms of lightweight modular sandwich panels made with EPS concrete as a core and fibre cement board as a skin.

- **Lightweight Modular Sandwich Panels**

  Multiple companies manufacture a wide variety of panels, including solid, hollow, reinforced, and sandwich panels, which are available with minimal variations in the manufacturing method and mix proportion specifications.

  Modular panels made of EPS and galvanised wire mesh are one such material that works well for quick construction as shown in Figure 1. It can be applied to up to G + 3-storey structures for roofs, walls, chajjas, curved roofs, domes, etc., as well as infill walls for multistory buildings. It can be finished externally with any type of finish, including stone cladding. To ensure proper positioning throughout the building stage, the location of services and

*Ph.D Scholar, Department of Civil Engineering, Mahindra University, Hyderabad,

**Ph.D Scholar, Department of Civil Engineering, Mahindra University, Hyderabad,

***Associate Professor, Department of Civil Engineering, Mahindra University, Hyderabad &

****Professor, Department of Civil Engineering, Mahindra University, Hyderabad

other elements, such as doors and windows (as shown in Fig. 2), must be decided upon in advance. In addition to this, the panels may also be made with polystyrene concrete as the core and concrete as skin as (shown in Fig. 3), along with the provision of tongue and groove for easy installation as depicted in Fig. 4. The current market involves the construction of lightweight sandwich panels through the installation of skin boards first, followed by the pouring of the core

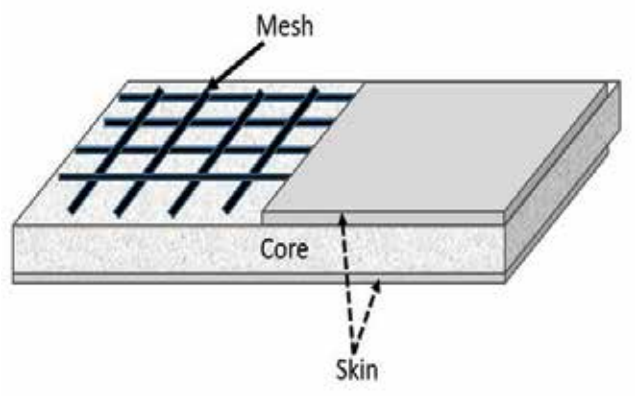

Fig. 1: Structure of Sandwich Panel with Wire Mesh

Fig. 2: Positioning of Windows and Doors

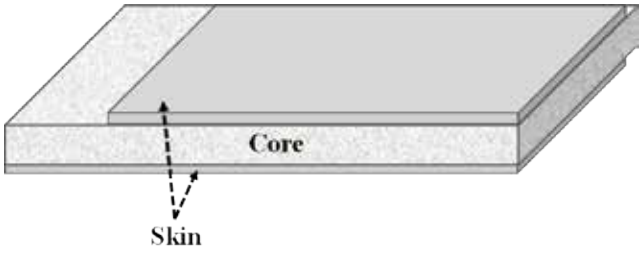

Fig. 3: Structure of Sandwich Panel

Fig. 4: Lightweight Sandwich Panel with Tongue and Groove Provisions

- **Potential applications**
  - Compound walls
  - Highway walls
  - Railway corridors
  - Airport boundary walls
  - Building envelope walls
- **Benefits**
  - **Economical:** The approach lowers the need for manpower, materials, and construction equipment, ultimately resulting in cost savings. As the product is lightweight, logistical expenses are also minimized.
  - **Structural stability:** The wall panels can withstand strong winds and earthquakes because of the panel's monolithic form, lightweight and composite nature.
  - **Construction speed:** Construction time can be lowered by up to 60% using a straightforward design procedure on the site, prefabricated panels, lightweight transportation, and rapid construction unit installation.
  - **Uniform quality:** Manufacturing of building components under controlled factory circumstances, precast construction ensures uniform quality and delivers reliable and uniform results in the finished structure.
  - **Thermal insulation:** For structures subjected to severe temperature conditions, the concrete sandwich wall panel made with insulating material is

an excellent option to meet insulation performance criteria.

- **Moisture-proof:** The modular panel is effective in keeping interior walls from absorbing moisture as there are very few joints.
- **Soundproof:** Compared to stone walls, the panels have better sound insulation properties, that can be further improved if needed by thickening the core.
- **Lightweight:** As the core is being prepared with lightweight material, the overall weight of the structure will be reduced by 30-50%.

- **3D Printing Concrete**

  Over the past two decades, Additive Manufacturing or 3D Printing gained attention in the global construction sector due to the versatile benefits compared to traditional construction practices. 3D Concrete Printing Market Size is projected to reach USD 9095.18 Million by 2031, growing at a Compounded Annual Growth Rate (CAGR) of 52%.

  3D Printing concrete deals with layer-wise deposition of the material according to the shape of the 3D model developed in CAD software. Many structures and habitats have been built using this technology in various fields some of them are defence posts, pedestrian

Fig.5: Complex Shapes and Textures of 3D Printed Walls [2, 3, 4]

bridges, artificial reefs, furniture and facades and residential buildings and dwelling units in and around the world. Especially in residential structures, the walls were printed to the required height maintaining the buildability of the layers one on each other. Fig.5 represents the complex shapes and textures of walls printed with concrete.

Benefits	Challenges
Freeform shape	Transportation
Less Manpower	Skilled workers
Time-saving	Material performance
Minimize material wastage	
Improved Quality Control	

The building element design of 3D-printed walls is similar to the concept of sandwich panels discussed in the earlier section 1.2, the external faces of the wall act as skin and depending on the functionality, suitable material can be filled in between the gaps of the printed layers further acts as the core. Such an example is shown in Fig. 6.

Fig. 6: Typical 3D Printed Wall-1 a) without filling and 3D PrintedWall-2 b) with filling [3,4]

- **Structural and Non-Structural Applications**

  The functionality of 3D Printed walls is significantly dependent on their cross-section. The cross-sectional design can change depending on whether the wall is meant to be structural or non-structural.There is a wide range of wall cross-section design options for non-structural 3D-printed walls or partitions. Possible options are shown in Fig.7, which includes hollow or filled single-or double-layer combinations. Wherever soundproofing or thermal insulation is required, a double-layer filled section is recommended because the filling materials improve the performance

In the context of structural walls, the design possibilities encompass four distinct wall patterns: block, zigzag, diamond, and full, which can be either fully or partially filled whereas the mechanical performance of the 3D-printed wall for structural application depends primarily on the materials, mix design and methodology adopted.

- **Effect of geometry and thermal performance**

  The effect of geometry and thermal performance are discussed to understand the importance of the shape of the 3D Printed walls.

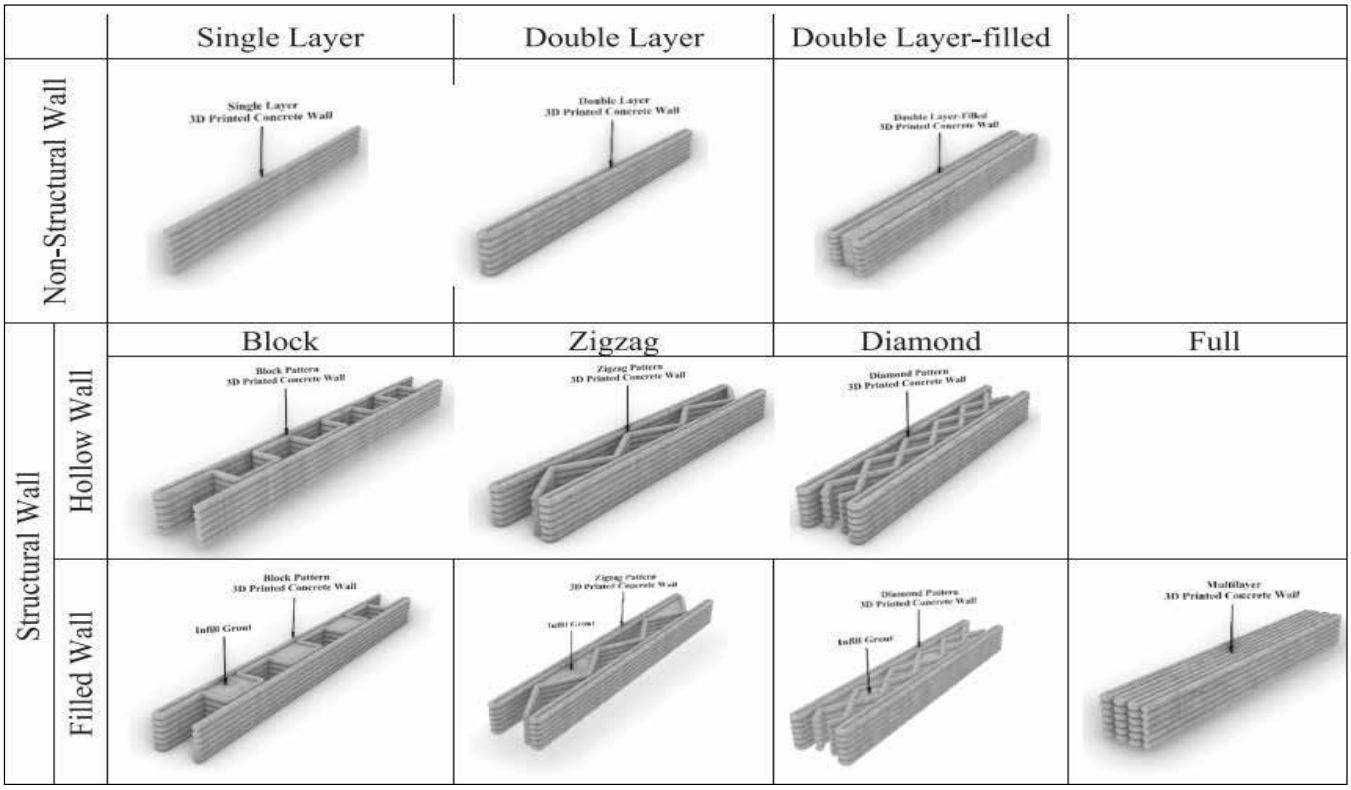

Fig.7: Possible Cross-Sectional Geometries for 3D-Printing of Structural and Non-Structural Sandwich Walls[6]

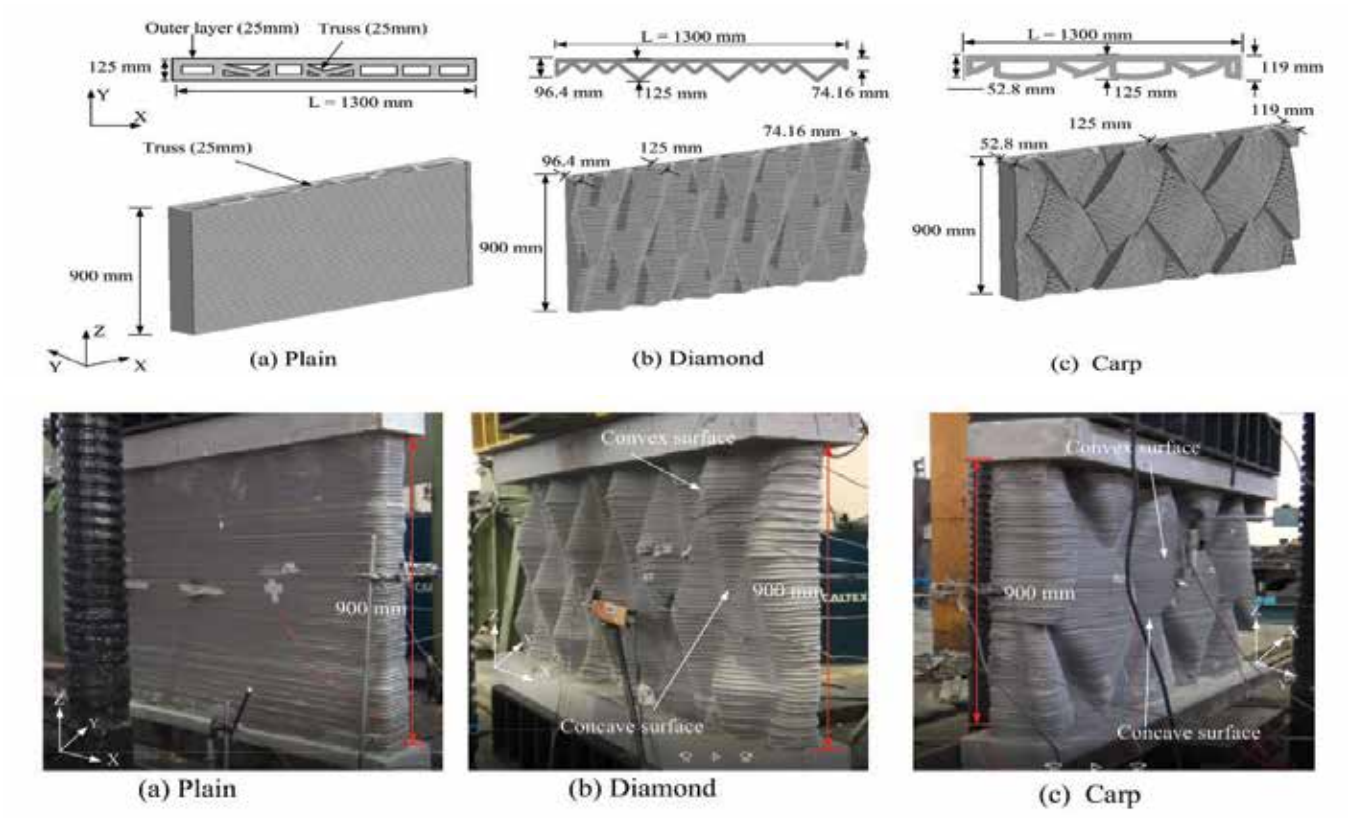

Fig.8: a) Shape and Dimension of the Tested Wallsb)Testing of 3D Printed Walls with different Geometries [5]

Case-1: Effect of Geometry

Three types of wall surfaces are considered, a) Plain b) Diamond c) Carp as shown in Fig. 8. The diamond wall performed better than the plain and carp walls in terms of load at the first crack and ductility due to the better distribution of stresses along the wall's surface.The load-deflection curve shown in Fig. 9 illustrates how the capacity of 3D-printed walls is influenced by geometry, highlighting the technology's advantage in providing flexibility in geometric design.

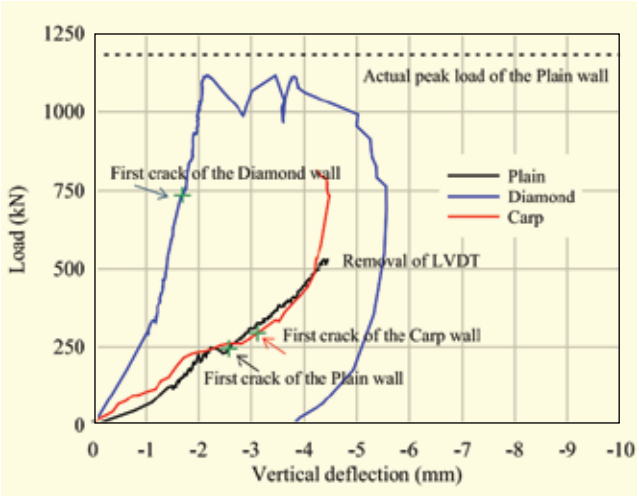

Fig. 9: Load Vs. Deformation graph of tested 3D Printed Wall Panels [5]

Case-2: Thermal Performance

The thermal performance of the exterior walls of two 3D-printed buildings located in the UAE was monitored and evaluated through thermal transmittance (U). The thermal transmittance indicates the heat transfer rate through the building's envelope. The two buildings were denoted as Structure 1 and Structure 2 as shown in Fig.10

The heat transfer rate drastically decreased when the large cavities in structure -1 were filled with the insulating material perlite. The additional exterior 3D printed layer in structure-2 provided continuous insulation on the outer side of the wall, thus creating a "more uniform thermal envelope" around the building, safeguarding the wall's thermal mass from abrupt temperature changes. This allows the thermal mass to function as a thermal buffer, absorbing excess heat during the day and gradually releasing it during cooler periods, leading to a more stable indoor climate.

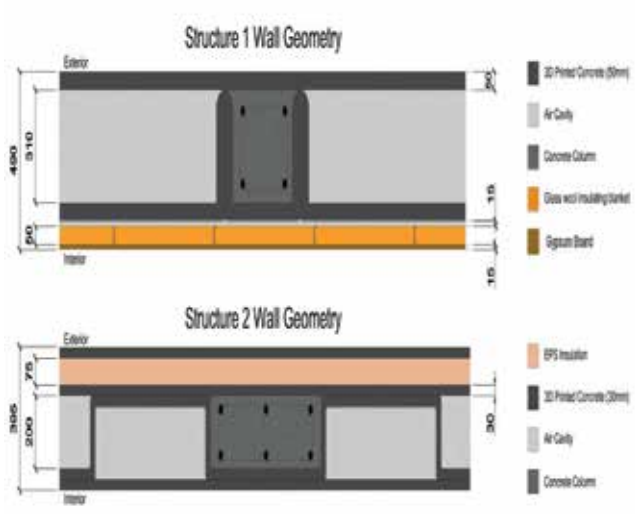

Fig. 10: Wall Geometries of structure-1 and structure-2 [7]

This highlights the importance of incorporating insulating materials as a fill-in can substantially reduce thermal transmittance by up to 60%, thereby improving the overall thermal behaviour of the wall.

- **Practical Applications in India**

  The scope for 3D Printing and Precast technology in India has huge potential because of their ability to revolutionize construction processes, reduce costs, and accelerate project timelines while promoting sustainability through efficient material usage.

  Some of the 3D printed and precast structures serving distinct functions are shown in Figs. [11-15]. These structures demonstrate the versatility and potential in modern construction practices.

  The precast concrete technique is currently being actively used in several large Indian constructionprojects. This technique is a robust and adaptable method where various concrete components or panels are manufactured with almost negligible waste in modern facilities by highly skilled workers under stringent quality control procedures. The practical applications that have been employed in India are depicted in the figures below [16-18].

Fig. 11: 3D Printed Wall, Chepauk Cricket Stadium, Chennai [12]

Fig. 12: Bus shelter, Godrej & Boyce, Mumbai [12]

Fig. 13: Housing unit Indian Defence, Indian Air Force - Chiloda, Gujarat. [12]

Fig. 14 (a): Two-Storey Structure for Indian Army, Ahmedabad [14]

Fig. 14 b): Post Office Building, Bangalore[13]

Fig. 15: (a) Summer House, Thiruvananthapuram [12]

Fig. 15: (b) Bunker-Shelter for officers and Junior Commissioned Officers, Western Sector of India [14]

Fig. 16: World's first 3D Printed Temple, Telangana [15]

Fig. 17: Solar Inverter room by Smart Built Prefab Private Limited, Nellore [16]

Fig.18: Mahasamruddhi express highway boundary wall by Smart Built Prefab Private Limited, Maharashtra [16]

3D PRINTING TECHNOLOGY TO MANUFACTURE SANDWICH WALL PANELS

- **Selection of printer:** The selection of printer fundamentally depends on the scale of the project and construction method,6-axis robotic arms and gantry systems are mostly used in on-site operations. Both technologies share the possibility of reaching a great printing area.
- **Geometry Optimisation:** Optimized geometry can save the material at unwanted locations without compromising the stability and performance of the sandwich wall. Examples of such optimized walls were discussed in the previous section 1.7.
- **Locally Available Materials:** Utilisation of Locally available materials can reduce transportation costs.
- **Waste materials or by-products:** Waste materials such as construction demolition waste, crushed brick waste and tailings from mining and excavation can significantly reduce the cost as well as carbon footprint. By-products such as Fly Ash, Ground Granulated Blast Furnace Slag, Rice Husk ash, Glass Waste, and Sugarcane Baggase Ash can also contribute to low-carbon concrete leading to less environmental effects and providing a circular economy.
- **Mix design:** The mix design should be tailored to meet the requirements of rheological properties during the pumping stage as well as printable properties.
- **Insulation:** Insulation strategies and materials such as perlite, sprayed-in-place options like cellulose, or foamed-in-place alternatives like polyurethane need to be considered in 3D printed walls to optimize thermal efficiency and promote sustainable building practices.

CONCLUSION

The continuously evolving construction sector requires innovative new materials and technology. Innovative technologies and materials require strength, speed, and sustainability. The best material and technology for the future are lightweight modular sandwich panels, that can match the demands of quality, sustainability, and speedy construction simultaneously integration of 3D Printing technology in the precast construction enhances the speed, cost-efficiency and design flexibility. The performance of 3D-printed wall panels is influenced by the geometry, insulation strategies, materials and mix designs. These variables play an essential role in determining the overall performanceof 3D-printed walls.

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TOWARDS CLIMATE CONSCIOUS URBAN DEVELOPMENT – RISKS, ADAPTATION, MITIGATION & URBAN RESILIENCE

V. SHOBHANA*

Abstract

Unprecedented urbanization at the onset of the 21st century aggravated the woes of inadequate basic services and energy crunch faced by cities in developing countries, foretelling crisis for urban environment. At the turn of its first decade, urban environment ran into further conflict with natural environment – becoming both a consequence and a cause of climate change. Sprawling cities ruthlessly exploited fossil fuels escalating GHG emissions. Unplanned peri-urban expansion altered eco-systems and micro-climates enhancing vulnerability to natural disasters. Realizing this at various levels, forums like IPCC (International) NAPCC (National) and SAPCC (State) have imparted not only a clarion call but also guidelines and Action Plan to address the aspect of climate change and urban planning.

Each city is unique in its issues, yet a common thread of challenges runs through them - their urban fabric gasps to breathe fresh air, sweats for lower temperature and struggles to keep afloat floods. With developing countries forced to bear the energy and climate burden of developed countries, this paper looks at the risks and proposed actions for mitigation and adaptation with urban planning as an effective tool.

THE CLIMATE AND CITIES VOCABULARY

Climate Change: Change of Climate that is attributed directly to human activity that alters the composition of global atmosphere and that is in addition to nature climate variability observed over comparable time periods. (UNFCCC 2005).

The key climate change indicator is the average global temperature that has been consistently increasing over the past decades, leading to warming and related changes to earth's weather systems.

Unprecedented changes in temperature and precipitation are leading to extreme and extended climate events as droughts, severe storms, flash floods, melting of glaciers, sea level rise, coastal erosion and associated flooding.

Human-created and natural factors collectively contribute to climate change and affect human settlements world over, the impact felt more by countries and populations with limited capacity to withstand or negotiate those impacts.

Climate Change Mitigation: Urbanization implies an increasing number of people moving to cities looking to livelihood and lifestyles involving energy-intensive occupations and consumptions. Exploitative utilization of natural sources has led to change in land-use patterns and enhanced atmospheric concentration of greenhouse gases(GHG), inducing an increase of global average atmospheric temperatures and thus climate change.

Actions to limit the amplitude of climate change by reducing the emission and enhancing the sinks of GHG form Climate Change mitigation. (IPCC 2001)

Climate Change Adaptation: Adjustment in natural or human-made systems in response to actual or climatic stimuli which scales down the harm or extracts beneficial opportunities complementing mitigation efforts at all scales. (IPCC 2001)

Urban Climate Resilience: The capacity of cities (systems) to function so that people living and working in them survive and thrive in the face of shocks and stresses related to climate change.

CLIMATE-CONSCIOUS URBAN PLANNING – CONTEXT & CHALLENGES

Global Context: Taking into account cities that are still growing world over, two-thirds of the global population is projected to live in urban areas

**Director (Arch & Cantt Planning), Military Engineer Services, Pune*

by 2030. Rising use of resources render urban activities responsible for 75% of GHG emissions while using a large proportion of world's energy supply for transport and buildings. While being major contributors, cities are also the areas most affected by climate change, thus present themselves as active sites for climate action.

70% of the cities world over are already suffering the cause-and-effect syndrome of climate change, with adverse impacts on basic services, infrastructure, housing, livelihoods and human health. Many countries have embarked on climate-conscious action – assessing specific risks and carving out mitigation and adaptation measures.

Indian Context: India will witness almost 40% of India's total population living in urban areas of various class of cities in 2030. In addition to creating built-environment for accommodating these urban dwellers and providing basic services and transportation, increased demand for energy and water, higher emissions and waste generation, deteriorating air quality and associated health impacts are emerging challenges to be addressed aggressively.

With 44% of carbon emissions having urban origins and 59% of GHG emissions coming from mega, metro and Class1 cities, India's urbanization comes amidst intense international concern about climate change and GoI's own commitments in the Paris Climate Agreement 2015 and NDCs subsequent to CoP26. Committed to urbanize while reducing the economy's energy intensity and fossil-fuel share of electricity, climate outcomes associated with urban transition become salient to national development contexts. This large-scale climate-conscious urbanization faces three determinant challenges:

1. Rising income levels and greater access to basic services and amenities will raise the future energy demand from transport, residential and industrial end-use significantly.
2. Urban India is prone to multiple climate risks – coastal surges, cyclones, precipitation, heat waves and temperature rise, which are interlinked and growing, and compound local stressors of population growth, land-use change and urban systems.
3. Buildings, streets, transport, infrastructure that are yet to be built will endure for decades and set the long-term pattern for consumption, waste and environmental and social vulnerability.

   The way India prioritizes efforts towards mitigation and adaptation will chart her vision to the simultaneous challenge of providing livelihood and services preserving local environment while managing increasing climate impacts.

CLIMATE CHANGE IMPACTS ON CITIES – RISKS AND VULNERABILITY

Being concentrated centres of people and economic activities as also of vulnerability to natural events and disasters, the expected impacts of climate change are going to be most profoundly visible in cities over a long time. Migration, land-use changes and spatial development have resulted in changing climate inside urban areas at micro-level adding to the risks posed by climate hazards causing cumulative impacts requiring complex solutions.

Urban systems, vital to urban areas, provide the following functions:

1. Spatial functions: Buildings to house people and commerce and space for social and economic interactions
2. Transport Functions: Movement of people, goods and materials to, from and around cities
3. Supply Functions: Provision of water, electricity, sanitation, drainage and waste management services

Climate change inducing vulnerability in urban systems may manifest in the form of extreme heat events, reduction in potable water, heavy rainfall, urban flooding and storm surges disrupting and destroying them. Yet there is a direct causal relationship between urban systems and climate change – to which energy-intensive systems dependent on fossil fuels make a contribution.

Urban features and infrastructure may exacerbate the vulnerability of urban spaces and systems. Hard surfaces reduce the absorption of rain water while increasing heat effect and temperature. High population density in urban areas can put pressure on green spaces – an important

environmental entity reducing heat, water run-off and air pollution.

While adversely influencing urban settlements and systems, climate change can also affect humans directly, exposing lives and livelihoods to risk. A tabulated form elaborating pertinent climate risks, their potential impact and the vulnerability generated is given below:

Table-1: Climate Change Impacts according to different Hazards

Climate Risk	Potential Impact	Urban System Vulnerability
Increased Temperature	• Ground water depletion • Water Shortages • Drought • Degraded air quality (smog)	• Increased demand for water supply • Additional waste water treatment • Exaggerated UHIE^
		• Increased energy demands for cooling • Increased rate of waste decomposition • Shrinking of wetlands • Polluted environment • Distress Migration
Increased Precipitation	• Increased flooding • Landslides/ mudslides	• Water logging • Overflow of sewage lines • Dilution of waste water to be treated • Loss of property (homes/ establishments) • Damage to infrastructure* • Displacement and population movement
Sea -Level Rise	• Coastal Flooding • Coastal erosion • Increased storm surge • Pollution of groundwater	• Saltwater intrusion in ground water • Contamination of potable water • Choking of drains • Loss of land due to erosion • Loss of property (homes/ establishments) • Damage to infrastructure* • Disruption to livelihood/ displacement
Extreme Weather Episodes (storms/ cyclones)	• Intense speed winds • More intense flooding • Higher risk landslides/ mudslides	• Property damage • Damage to infrastructure* • Disruption to livelihood/ Displacement

^ Urban Heat Island Effect
* Transportation, energy, communications

Source: Ghoneem, M. Y. M. (2016). Planning for Climate Change, Why does it Matter? (From Phenomenon to Integrative Action Plan). Procedia - Social and Behavioral Sciences, 216, 675–688.

PLANNING FOR CLIMATE CHANGE – ADAPTATION AND MITIGATION

As it becomes evident that urban systems contribute significantly to climate change on the one hand and stand to suffer heavily from its effects on the other, it becomes imperative that concerted responses are required to reduce and manage the impacts of these effects so as to reduce urban vulnerability and enhance urban resilience. Urban planning is an important tool to initiate mitigation and adaptation measures for tackling rise in global temperature, extreme weather conditions and climate-change related risks.

Development of urban settlements and land-use planning are crucial sectors in which cities should mainstream mitigation and adaptation strategies. Sensitizing the population towards adaptability to adverse events and initiatives by local authorities in working out city-level actions are also pertinent aspects.

Following are the components of urban planning for climate action: (City of Woodlands CAP)

1. Energy
2. Transportation and Land-Use Plan
3. Water and Waste
4. Urban Forest and Open Space
5. Municipal Operations
6. Public involvement

Mitigation and Adaptation Strategies:

The need to strengthen the response to climate-change with cities at the forefront of climate mitigation and adaptation was first discussed in CoP26 (C40). Mitigation and Adaptation are strategies for climate change management entailing planning for uncertainty. Mitigation is action to reduce emissions that cause climate change. Adaptation is action to manage the risks of climate change impacts. (NAPCC India)

Adaptation: Short term strategy involving preparing for system changes, reducing vulnerability by understanding climate hazards, reducing exposure and sensitivity constitute adaptation.

Adaptation addresses the consequences of climate- change such as heavy rainfall, flooding or extreme temperature and helps societies deal with their unavoidable impacts. Policies for adaptation have a crucial bearing on responses to climatic event, but have been hitherto under emphasized.

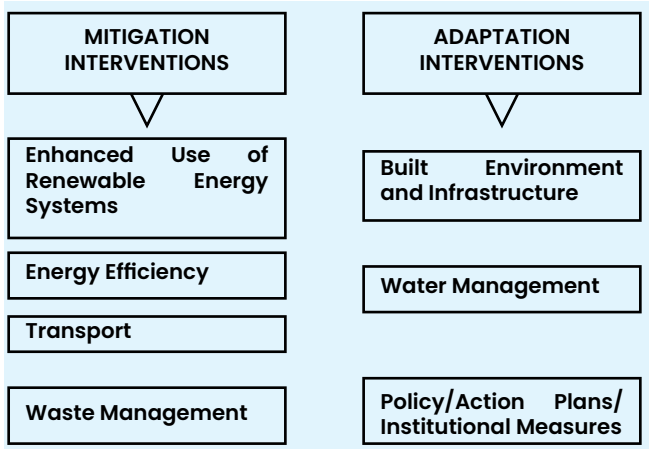

Fig. 1: Mitigation and Adaptation Interventions

Source: Adapted from Saurav Chowdhury Suchismita Mukhopadhyay Sakshi Gaur, Background paper: Cities and climate change – The Indian context WWF Report (1986)

Adaptation can be 'Reactive' – which involves a deliberate response to a climatic shock or impact, in order to recover and prevent similar impacts in future or 'Proactive' – which involves planned action in advance to prepare for, minimize the potential impacts and reduce the risks associated with climate-change.

The benefit from adaptation can be direct for a city, its communities and ecosystems.

Mitigation: Long term strategy to reduce GHG emissions by type, source and location constitute mitigation.

Quantifying GHG emissions attributable to cities is a fundamental step for climate-change mitigation. With the theory that emissions must be measurable to be manageable, methodologies for measuring have been worked out as per IPCC guidelines.

Geographical attribution apart, a variety of factors influence a city's emission profile. These factors include urban form and land-use patterns, climate, building design and technology, transport modes and income levels. Cities can learn and adapt measures from one another.

The benefit of mitigation are indirect in the form of political or economic gains or improvements in local environment after a long lead time.

URBAN PLANNING – FROM SUSTAINABILITY TO RESILIENCE

Adaptation actions and mitigation actions are integral when dealing with comprehensive Climate Change Management strategy and are interwoven approaches for long-term sustainable, integrated urban planning. The basic facets of a comprehensive programme for combating climate risks and reducing vulnerability to them combined with a development programme for long-term sustainable urban planning are:

1. Physical infrastructure (Buildings/ Transportation/ Roads)
2. Energy and Communications infrastructure
3. Social infrastructure (Health/ Education services)

Climate-change mitigation and adaptation interventions for reducing energy-use, carbon emissions and UHIE, for water efficiency and conservation and for carbon sequestration can be outlined under these aspects:

(I) Land-use Planning:

1 Identification of climate-proof urban areas for development

2. Land-use regulations and building codes (Zoning)
3. Compact urban development/ densification reducing land consumption
4. Relocation of buildings/establishments vulnerable to climate-change risks

(II) Sustainable urban form and structure:

1. Retrofitting and building of settlements (elevation of buildings vulnerable to flood)
2. Revising, reviewing and enforcing building codes and design standards
3. Use of passive and renewable systems / such renovations in existing buildings
4. Building design for material reuse and recycling

(III) Green Mobility/Accessibility:

1. Pedestrians paths/ bicycles
2. Robust public transportation
3. e-vehicles

(IV) Water Efficiency/Conservation:

1. Increasing capacity of storm water collection systems
2. Increasing absorption of surface water/ collection of rainwater
3. Recycling waste-water

(V) Green infrastructure:

1. Flood resistant infrastructure (levees/ dykes)
2. Urban forests/ parks/ trees
3. Wetlands/ marshlands
4. Porous pavings and green roof

With institutional, political and financial frameworks completing the set of factors involved, improved urban environmental outcomes, reduced vulnerability and sustained preparedness for climate risks will have cities embarking on the path of climate-change resilience.

FROM URBAN RESILIENCE TO CLIMATE CHANGE

Cities, most of them already reeling under impacts of climate change, are crucially placed as hubs of potential solutions for climate-change – both in mitigation and in building resilience. Climate smart planning by integrating climate-change in urban planning will determine the extent and impact of climate change – and the ability to achieve emission reductions as well as the capacity to adapt to changing circumstances, especially addressing the defining sectors of energy, building, mobility and waste management.

Developing such adaptability in essential services, infrastructure and population that enables a city not only to restore to normal in the shortest time possible but also to thrive in the face of volatile shocks or stress is core to climate adaptation for urban resilience. It involves a strategic shift towards crisis-proof development that is sustainable, equitable and inclusive as well.

Urban climate change resilience recognizes

the complexity of the uncertainty associated with climate change and the rapidity of growth urban areas while embracing climate-change adaptation and mitigation and disaster reduction actions. The approach to urban resilience considers cities as dynamic systems capable of evolving, adapting and surviving, being resilient at three levels:

1. The urban systems of the city survive shocks and stresses
2. The people and the organizations are able to accommodate these stresses in their day-to-day decisions
3. The city's institutional structures continue to support the capacity of the people and organizations to support these aims

A resilient city will make significant decisions on planning, land-use and major investment projects - effectively managing the challenges of current development while considering future scenarios of climate change – focusing on resilience of system rather than of infrastructure.

CLIMATE-CHANGE RESPONSES

In the universality of above postulations and premises, where does India stand? Hailed as one of world's fastest growing economies, Indian cities are ground for rapid urbanization and growing population – and face challenges related to provision of basic necessities such as housing, transport, water and electricity. This implies increased demand for energy and water, higher emissions and waste generation, deteriorating air quality and associated health concerns.

GHG emissions originating from transport, buildings, industry and waste have shown an upward trend making cities vulnerable and suspect to huge risks of heat island effect (UHIE), increased water stress and frequency of extreme weather events as urban floods and droughts.

Major cities, already facing poor air quality, have witnessed loss of life and property, disruptions to transport and power and incidences of epidemics attributable to extreme events arising out of climate-change and other associated factors of urbanization. Bengaluru, Chennai, Delhi, Jaipur and Kolkata are among 970 cities marked globally whose population will be regularly exposed to extremely high temperatures. Chennai and Mumbai are among 570 cities globally whose people will be vulnerable to sea level rise and coastal flooding. Recent events of flooding in Surat, Kolkata, Mumbai and Chennai and instances of all-time high temperatures in many cities reinforce urgent need for concerted action to plan for climate change with urban development as the central theme.

Evolution

The earliest Indian urban climate concerns were addressed by local networks scattered geographically and established around local climate vulnerabilities and stresses, disaster risks and related infrastructure deficits. The focus was varied – in Ahmedabad it was heat stress, in Surat, Chennai and Kochi the risk of sea level rise and flooding, in Delhi air quality, in Indore water scarcity and in Gorakhpur water-logging.

In the absence then of National or State level perspective, cross-cutting solutions for alleviation of risks and adaptation to adverse events were promoted by a number of city departments involved in urban planning, coastal management and real-estate development. Consistent with changing international climate context and India's 2009 (Copenhagen) and 2015 (Paris) pledges of economy linked carbon reduction targets, scope of adaptation broad ened to include GHG emissions, energy-efficient and renewable energy technologies and phasing down of fossil-fuels.

Focus and Frameworks

With accelerated energy consumption and escalating emissions, urban centres became active sites for deployment of technologically and politically feasible energy-efficient and low-carbon end-use options. To streamline and institutionalize these actions, national policies and programmes were initiated covering a wide range of aspects - urban services, settlements, infrastructure, renewables – all having a component of climate conscious adaptation and promotion of resilience. Those relevant here are:

1. National Action Plan for Climate Change (NAPCC) – Launched in 2008 to mitigate and adapt to the adverse effect of climate change.
2. State Action Plan for Climate Change (SAPCC) – Prepared by 34 States/UTs

with focus on adaptation oriented urban development.

3. Climate SMART Cities Assessment Framework (CSCAF) – Launched in 2019 providing roadmap for urban India to combat climate change towards sustainability and resilience.
4. City Climate Action Plan (CCAP) – A key indicator in CSCAF, guidance to cities/ local governments for development of climate adaptation and mitigation strategies at city level. Mumbai being the first city to come up with such document, many cities across States have developed futuristic action plans.

CONCLUSION

As a country on the threshold of undertaking one of the largest urban transition, India is gaining credence in international discussions promoting urbanization-oriented climate outcomes in national development contexts. The global city network C40 – a united front of cities to confront climate change – has six member cities from India – Bengaluru, Chennai, Delhi NCR, Kolkata, Jaipur and Mumbai. The Global Covenant of Mayors for Climate and Energy (GCoM) – an international alliance of local governments supporting voluntary action to combat climate change has Ahmedabad, Bhavnagar, Junagarh, Gandhinagar, Gangtok, Gwalior, Jamnagar, Kochi, Nagpur, Panaji, Rajkot, Shimla, Surat and Vadodara as partner cities. Pune, Surat, Chennai and Jaipur are part of 100 Resilient Cities – a forum looking to build urban resilience across the globe.

Climate-conscious agenda firmly entrenched through national initiatives and a range of cities having responded with clear action plans, tactical understanding of interacting climate and development priorities across governance levels will condition future trajectory of climate responses. Air, water, transport and energy addressed, decisions about urban form, lock-in effects of energy and carbon consumption of which will manifest long-term, are still open. Prioritizing policies concerning urban sprawl and strategic densification will consolidate the path to resilient urban development.

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PUBLIC TRANSPORT DURING HEALTH CRISIS: CHALLENGES & INNOVATIONS

Dr. Pawan Kumar* and Preeyal Jyotika**

Abstract

Public Transport and Public Health are associated with each other through well beings of the commuters and the city residents. Urban transport provides access to the health services but at the same time, various modes of transport affect physical and mental health of the commuters due to longer waiting time, commuting time, transfer time at interchange points, convenience, fatigue, etc. In health crisis situation like severe acute respiratory syndrome corona virus in 2019, the operations of urban transport became challenge for both operators and transport authorities. Further health crisis situation also affected the operations and managements of urban transport. Therefore, development of world class transport infrastructure through urban planning is need of the hour to maintain the mobility services, support social inclusion and facilitate social interactions. The branded image of public transport as "Safe Mobility Choice for All" should be maintained for every passenger in both normal and health crisis situation. Therefore, concerned agencies should opt various measures of hygiene, cleaning, sanitary protocol, contagions issues, etc. as well as crisis management of the health policy in operations and management of public transport.

INTRODUCTION

Public health crisis situation may be defined as sequences of events creating public health threat where limited time is available in treatment making process and large degree of uncertainty involved in normal response capability. In other words, health crisis situation may be complex health system in difficult situation that affects human beings from a particular locality to whole town/city across the country and continents. It includes new infectious diseases, fast moving process of pathogens & vectors of diseases in new areas, contagion, etc. Recently, Corona virus disease (COVID-19) was an infectious disease caused by the SARS-CoV-2 virus and presently it remains a persistent public health threat due to mutation of virus.

In this context, it is well understood that public health crisis affects mobility in cities across the countries. Similarly, operations and services of public transport may also spread the diseases in the cities. During public health crisis situation like Corona Virus Disease 2019, public transport was considered as "Transmission Vector" to spread corona virus and therefore providing safe mobility facilities to the commuters and the passengers became challenging task for both transport authorities and operators.

In fact, any pandemic strongly affects mobility around the globe which further reduces ridership but increase the operational losses. The most of the people avoid using public transport due to feeling risk of contagion and prefer to use car, two wheelers, bicycles, walk, etc. Such approach change individual perception for public transport and people's behavior to use public space particularly crowded and busy areas.

Contrarily, the public transport is only system which provides mobility of front-line workers and maintained the supply chain during lockdown and health crisis situation. In other words, if public transport is safe for front-line workers with cleaning and disinfection measures then the same may be safe for other passengers by managing the

*Town and Country Planning Organization, New Delhi.

**Student of Indira Gandhi Delhi Technical University for Women, Kashmere Gate, Delhi.

occupancy level in buses and metro with all precautions and sanitary measures. In fact, public transport is not likely to cause danger, harm or risk for mobility of both passengers (medical staff, police personnel, Govt. officials, etc.) and essential goods to keep city alive, humane and breathing.

PUBLIC TRANSPORT IN HEALTH CRISIS SITUATION

New School of Thought

The health crisis situation has significant impacts on individual health, community health, public health, as well as loss of life and economy. During pandemic in 2019, the corona virus disease affected the mobility spectacularly and restricted the movements. It was believed that public places such as institutions, offices, halls, malls, etc. as well as public transport may be a possible source of contagion. At that time, a new school of thought was evolved that crowded, overcrowded, unhygienic, poor maintained conditions of public transport is one of the possible sources of spreading corona virus through the passengers in different parts of towns and cities.

It may be grounded as formation of contamination zones in different part of the city. Many contamination zones were identified and isolated. Likewise, people also tried to reduce their movements and social contacts for reducing the risk of infection. In this context, "New Trends of Mobility" during health crisis situation come in existence as per requirements of health sector, transport sector, public safety, education sector and employment sector.

New Trend of Mobility

The equilibrium between demand and supply of public transport make a system more sustainable and viable but health crisis situation like corona virus disease has brought severe disruptions and suppressed demands to public transport. The sudden annoyance of lockdown and restriction created chaos at bus depots, railways stations, inter-state bus depots, etc. as they became much more crowded. Further, it also affected passenger priorities and preferences towards public transport adversely. The night time restrictions, day time restrictions, and weekend restrictions forced people to have own personal vehicles. In other words, the dynamics of cities changed and pace of city reduced. In these situations, new trends of mobility were observed and some of them are as follows:

- **Mode Choice of Public Transport**

  The mobility was changed in terms of travel distance, purposes of trip, mode choice, route assignments, etc. during the different phases of the pandemic. The space near bus stops, bus depots, taxi stands, etc. did not fulfill criteria for physical and social distancing. Further, limited operations of public transport during lockdown, uneven accessibility to public transport, inadequate amenities and facilities, etc. made journey less desirable and more threatening. These factors affected modal choice behaviors of the passengers.

- **In-vehicle Public Space (IVPS) and Out-vehicle Public Space (OVPS)**

  The mobility restrictions, stay-at-home regulations, work from home, full & partial lockdowns and various other social restrictions have directly influenced day-to-day transport flow particularly for work trips in urban areas. The space inside the vehicles and outside the vehicles at bus stops, bus depots, metro stations are very crucial in journey trip. Generally, the high quality space inside the vehicles is not maintained. However, the space is well maintained and managed at metro stations but it prejudiced the norms of 'space design' and 'space standards' for healthy and safe mobility.

- **Increase in Personal and Private Vehicles**

  The people shift to personal and shared private modes of transport due to higher perceived risks associated with public transport. It requires the residents to purchase personal vehicles particularly two/four wheelers for safe, hale and hearty mobility.

The increased personalized vehicles damage the sustainability of public transport and put extra pressure on transport infrastructures. Such situation emphasizes new approach to manage whole transport system with high travel demands for personal & private vehicles and low demand for public modes of transport.

ENVIRONMENTAL UP-GRADATION

The health crisis situation apply break on speed of mobility and slow down the production and economic activities which contribute considerably in reduction of GHGs emission, air & water pollution, etc. Therefore, air quality in various cities significantly improved. Contrarily, increase of medical waste, haphazard use and disposal of disinfectants, PPE kits, face masks, gloves, Plexiglas, respiratory protections, plastic screens, etc. threat the environment.

SHARED MOBILITY: NEW DIMENSION OF FINANCIAL SUPPORT

In health crisis situation, the share mobility always faces same challenges as the public transport. The different person using the same vehicle at the same time or immediately after each other has the same risk of infectious virus from the fellow travels. The same risk is also associated with the driver and staff. Therefore, business of shared mobility services such as shared taxi, car-sharing, bike-sharing, ride-hailing, ride-sharing, etc. is fallen down.

Ride-hailing services provide access to only an individual, and no other unknown co-passengers can join that particular ride in between. At the same time, more than one passenger can book the same cab for different destinations in ride-sharing services. In some of the cases, ride-sharing services are shifted to ride-hailing only. However, extra costs for protection of drivers, passengers and supporting staff from infection as well as financial support to drivers and staff tested positive by virus disease or exposed to it, put extra pecuniary burdens to the companies.

In these circumstances, new dimension of financial support models have been observed worldwide. Some of them are in shown in Table 1 as follows:

Table 1 : Financial Supports in Shared Mobility Sector during Health Crisis Situation

S.N.	Shared Mobility Services	Financial Incentives
i	DiDi Chuxing (Mobile Transport Company, Beijing, China and in other Countries)	For Drivers infected and got loss of income, China's Didi set- up US$10 million fund for drivers who test positive for corona virus. DiDi also set-up US$ 10 million funds to support its overseas drivers cope with the effects of corona virus pandemic particularly in Australia, Brazil, Japan, Mexico, Costa Rica, Panama.
ii	Ola Services (Ola Foundation) Ola as India's largest mobility platform and one of the world's largest ride-hailing companies, serving 250+ cities across India, Australia, New Zealand, UK.	Ola launched 'Drive the Driver Fund' to offer relief to the driver community. It supported auto-rickshaw, cab, kaali-peeli and taxi drivers, through contributions from the Ola group, investors and via crowd funding platform for citizens and other institutions. It also helped welfare and up-liftment of drivers and their families who had been affected by the restrictions due to the Covid-19 pandemic.
iii.	Grab Malaysia	Grab Malaysia introduced "Ride Cover" policy to include coverage for corona virus and financial support to drivers. Policy was to help ease the financial burden of driver-partners who were hospitalized. Grab Malaysia provided financial assistance, rental waivers, insurance protection, and earnings supports.

S.N.	Shared Mobility Services	Financial Incentives
iv.	Scheme for : Permit Holders (Drivers) and Public Service Badge (Drivers) , Govt. of NCT Delhi.	Financial assistance of Rs 5,000/- to Permit Holders (Drivers) of auto-rickshaws, e-rickshaws, taxis, Phat Phat Sewa, eco-friendly Sewa, Gramin Sewa and maxi cabs in view of the financial hardships. Financial assistance of Rs 5,000/- to all individuals holding Public Service Badge (Drivers) of para-transit vehicles and permit holders of para-transit public service vehicles.
v.	Quarantine Order Allowance Scheme and COVID-19 Driver Relief Fund (CDRF) Scheme, Singapore	The Govt. of Singapore provided Quarantine Order Allowance for those drivers who were served Quarantine Orders after coming into close contact with individuals who tested positive for infections. CDRF scheme was also provided for taxi and Private Hire Car (PHC) drivers affected by corona infections.
vi.	Lyft Ride Share Company, USA	Corona virus Aid, Relief, and Economic Security (CARES) Act was signed. It aimed to ease the impact of COVID-19 and provided support to millions of working individuals and families across the country, including drivers on the Lyft platform.

Source: Data collected from various sources and hence represents approximate information

CONCEPTS OF TRANSPORT

During the pandemic, Walking and Cycling supported the social/physical distancing and relieved the burden on public transport. Many innovative concepts in non-motorized transport (NMT) sector were developed, some of them are as follows:

- Concept of "Pop-Up Bike Lanes"

  It is also known as emergency bike lanes. It is nothing but temporary bike lanes that enable social distancing for cyclists and relieve public transport system. The concept was first realized in Bogotá to relieve the Transmilenio BRT system. The city has set up a network of emergency bike lanes (Bogotá already has 550 Km of permanent bikeways). After that many other cities such as Berlin, Paris, Brussels, etc. adopted the same concept.

  The advantage of 'Pop-Up Bike Lanes' is that the same may be converted and used as permanent cycling lanes which may contribute and enhance NMT infrastructure in the city. Many cities use the same as 'Open Streets' where automobile traffic is closed but the same is open temporary for walking, bicycling, dancing, playing, socializing, etc.

  Further, Open Streets allow replacing of automobile traffic for a few hours and same streets are used as massive public space for physical and social activities. The advantage of such open Street during health crisis situation is that it maintains safe distance from the buildings and close to residences. Therefore, Open Streets also known as "Streets for People" fulfilled requirements of city residents.

- In New York City, People prefer to use 'Citi Bike' to avoid using the subway. The use of e-bikes has been encouraged to provide take-outs and deliveries from the restaurants to the city residents.

- The city of Vienna, the capital of Austria, published "Cycle Network Map" to facilitate cycling. Berlin, the capital and largest city of Germany by both area and population, kept bicycle repair shops and bicycle dealers open during planned lockdown to support resilient and sustainable mobility.

CONCLUSION

- The health crisis situation puts pressure on transport infrastructure and restricts movements of public transport. It may also due to both health and security issues. In this context, it is necessary for transport authorities to untie new windows of travel options and efficiencies for the passengers rather than restricting access and choices. Such

preparedness may provide better mobility in health crisis situation.

- The public transport particularly metro is efficient and low emission mode of transport. The mode choice of metro for the passengers may not have a significant variation in both normal and health crisis situation as there is hardly substitute of metro services. Therefore, Standard Operating Procedures (SOPs) for implementation of safety measures during health crisis situation can provide secure and accessible public transport (metro) to all city residents.
- Public transport particularly bus services is more wide, spread, accessible and affordable to all income groups of the city residents. It is significant to enhance e-buses particularly medium sized electric buses as low emission public transport for better and healthy movements of the city residents.
- The health crisis situation compels the people to change in their daily journey behaviors. The physical activities are reduced due to work from home, closures of gymnasium & fitness centre and restricted movement in proximity. In such circumstances, non-motorized transport (NMT) becomes useful alternative for mobility. Further, such health crisis provides a platform to promote NMT in towns and cities through designated cycling lanes, pedestrian-only streets, create pedestrian crossing infrastructure such as tabletop, pedestrian signals, pelican crossings, etc.
- The health crisis situation emphasizes to build resilience in public transport system. The modification in space design and space planning at bus stands, bus depots, metro terminals, interchange hubs, etc. should be incorporated in layout design. Further, it is manageable to reduce the risks associated with health and other contagions issues up to at a certain level by taking appropriate measures. Then, the same public transport may also be acceptable to passengers. Such paradigm shift can restore assurance in transport authority, confidence in transport services and improved image of public transport.
- The crowd management in metro and buses is always challenging tasks for transport operators. The crowd related information of each metro coach can help the passengers for optimizing trip to minimize crowds. It also holds well in normal conditions of the trips. The branded image of public transport as "Safe Mobility Choice for All" should be maintained for every passenger including elderly, children, disabled, senior citizens, women, etc. in both normal and health crisis situations. Therefore, transport authorities should opt various measures of hygiene, cleaning, sanitary, contagion, etc. as well as crisis management of the health policy.
- The urban transport is always connected and inter-linked with challenges of public health, climate change, road safety, pollution, etc. but health crisis situation add another dimensions of sanitary crisis and contagions issues in operation and maintenance of public transport. The short term emergencies and long term actions should be considered as part and parcel of transport policy. It may help in recovery and survival of transport sector as well as delivering the mobility services to the society.

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SEISMIC RETROFITTING OF HISTORICAL BUILDINGS USING STRUCTURAL CONTROL

Dr. B. P. Suneja*

Abstract

The monuments that represent an architectural and/or cultural signature of an era are popularly known as Historical Buildings. They give a sense of pride and belongingness by connecting us with our ancestors. It is our moral duty to preserve these buildings, of historic importance, for future generations. Seismic retrofitting of historical buildings is considered as a major challenge to civil engineers and other professionals. The retrofitting strategy for such buildings should be able to preserve their unique feature along with the seismic strengthening. Seismic retrofitting strategies can be categorized as Demand based (i.e. earthquake input) and Capacity based (i.e. seismic resistance of building). Most of the conventional techniques of seismic strengthening are based on the capacity enhancement of the structure whereas the structural control methods are based on the reduction in demand. The demand based methods have become much attractive for historical buildings as they require least visible interventions hence, the intrinsic worth of the monuments can be preserved. This paper is an effort to address the important seismic characteristics of historical buildings and various technical issues involved in retrofitting of these buildings. Also, it describes the effectiveness of using control methods particularly, the base isolation techniques for such important structures. Finally, the challenges in the selection of an effective isolation strategy for retrofitting of historical building have also been addressed.

INTRODUCTION

The historical buildings are the structures possessing an intrinsic worth, regardless of their date of construction and are considered as an architectural/ historical/ cultural masterpiece of a particular era. They connect us with our ancestors and give a sense of pride & belongingness. Therefore, it is the obligation of each generation to preserve these valuable structures and their unique features for future generations. Unfortunately, most of these monuments being masonry structures with some typical features are vulnerable to earthquake forces. For retrofitting of these buildings, it is necessary to preserve their intrinsic worth in addition to seismic strengthening. Therefore, most of the conventional retrofit techniques which allow large amount of intervention are not suitable for such buildings. The other approach of seismic retrofitting is based on the principle of reducing demand. It does not allow large amount of visible intervention hence, preserves the historic value of the structure. *Structural Control Methods* fall under this category. These methods can essentially be divided into *active* and *passive* control. The *Passive Control Methods* are different from the active one in the sense that they do not require any external force to activate the control. The concept of Active Control is comparatively recent and its application is mostly limited to new structures. On the contrary, Passive Control concept, particularly, the Base Isolation Technique is in its most advanced stage and has been used for seismic retrofitting of some of the important existing structures namely, San Francisco Golden Gate Bridge [Elsesser E. et al., (1991)]; St. Pietro Church, Italy [Sparacio R., et al., (1993)]; Mackey Schools of Mines at Univ. of Nevada [Kelly J.M., (1993)].

This paper briefly describes the typical seismic features of historical buildings, their possible failure/ damages and the technical issues involved in the seismic retrofitting of these buildings. Possibility of implementing the structural control methods as retrofit strategy for historic monuments and the related issues has also been addressed explicitly. Finally, the effectiveness of *Base-Isolation* technique in comparison to the existing conventional retrofit techniques for historical buildings has been discussed.

*Former Professor, Civil Engineering Department, Rajasthan Technical University, Kota, Rajasthan

SEISMIC CHARACTERISTIC AND POSSIBLE DAMAGES OF HISTORICAL BUILDINGS

Typical Structural Characteristics [Michel Bruneau, (1994)]: Traditionally, most historical buildings are pre-twentieth century masonry structures and were constructed on the basis of experience of the masons/ builders alone. No well-defined design methodology or the codal provisions were available then. Main consideration was given to their geometry, effect of gravity load and aesthetic quality and least attention was given to the lateral resistance or ductility. In these buildings, the most commonly used materials were stone, unfired / fired clay bricks and lime mortar. Typical structural features of these buildings are: complex geometry, heterogeneous and non-homogeneous construction, heavy weight, low lateral strength, lack of ductility, lack of continuity/ integrity of various structural members, presence of large/ bad-positioned openings etc. which make them vulnerable to seismic attacks. Major seismic damages to most of these historic buildings occur mainly due to poor ductilityand weak structural connections between walls, floors, and foundations. Further, the heavy weight of construction materials makes these structures more vulnerable to earthquakes. In general, masonry structures can be categorized as typical rigid structures with short period of vibration. Seismic analysis of such buildings shows that the values of effective peak ground acceleration are in good correlation with the induced seismic forces which leads to typical structural and non-structural damages. Also, the seismic resistance of these buildings may further be reduced because of deterioration of the masonry due to environmental attacks and lack of maintenance. Although, these buildings were not originally designed for earthquake loads but most of them are found to provide some lateral resistance to earthquakes due to their regular shape, presence of thick load bearing walls, and large number of shear walls which can transfer the lateral seismic forces safely.

Possible Modes of Failure: On the basis of seismic damage studies carried out for buildings, the most common types of failure mechanism identified are as below and shown in Fig. 1 [Miha Tomazevic (1999), pp. 31].

- **Wall Diaphragm Separation:** In this, various structural elements tend to separate out with each other and start behaving independently under the strong seismic shaking, mainly due to lack of integrity.
- **Out of Plane Wall Failure:** In this, the external walls behave as cantilever along the building height and may fall in an 'out-of-plane manner'. For the historical buildings of masonry walls, this type of failure is most common and vulnerable.

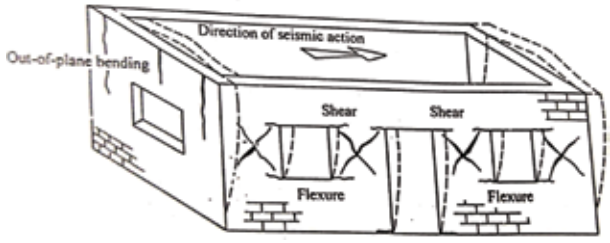

Fig. 1: Typical Modes of Failure/ Damages to Masonry Walls (Ref. 4 pp. 31)

- **In Plane Wall Cracking:** Two types of failure modes are possible under this category: (i) Sliding shear failure mode is characterized by shearing of wall along horizontal mortar joints under a low level of vertical loads and is common in upper storey and (ii) Shear failure mode is one of the most frequent failure modes and characterized by double diagonal cracks (X) in the walls. It mostly occurs in lower storey/ in the narrow portion of walls situated between the subsequent openings. Fortunately, until the shear cracks become highly severe, the gravity-load carrying capacity of the walls is not jeopardized.
- **Flexure Failure Mode:** Though rare, this type of failure mode is possible since the walls do not have tensile bearing capacity. It may occur as a result of wall diaphragm separation.

PRINCIPLES OF RETROFITTING FOR HISTORICAL BUILDINGS

Strengthening of ordinary buildings can be done with large amount of visible interventions, as we are much concerned with the *strengthening aspect* rather than the *preservation aspect.* On the contrary, for historical buildings both these aspects are equally important. While undertaking seismic retrofit strategy for historical buildings the following *preservation principles* are kept in mind:

- To preserve and retain the historic materials to the greatest extent possible and to ensure the new seismic retrofit systems visually compatible with the intrinsic features of the building.
- To adopt "reversible" type retrofitting work so as to allow removal for future use of improved systems and traditional repair of remaining historic materials.

For devising the most appropriate and cost effective retrofitting strategy for a particular historical building, a coordinated team effort is required to collect the following information:

- Importance of building and its historic character.
- Material and geotechnical characteristics and methods of original construction.
- Configuration of the historic structure and inherent areas of weakness.
- Details of previous repair/ restoration, history of damages of the building and that of the adjacent buildings under previous earthquake/s.
- Analyze the behavior & projected risk of seismic damage of the building.
- Identify the use and duration of occupancy of the building during retrofitting process.
- Relative weightage of *strengthening* and *restoring* aspect.
- Budgetary constraints and to weigh the costs and benefits of undertaking seismic retrofitting.

(Sometimes the economy factor takes a back seat over socio-political/ legal factors for final decision.)

CONVENTIONAL RETROFITTING TECHNIQUES

Some of the most common existing techniques are [Tomazevic M., (1989) & Breiholz D.C., (1991)]: grouting technique; introducing reinforced cemented network into the walls; providing reinforced cement core; providing pre-tensioned cables from roof to wall and floor to wall etc. As most of these techniques involve least visible interventions they are suitable for retrofitting of historical buildings. Unfortunately, these techniques are more effective for mild earthquakes only. Also, the impurities present in the cement grout may damage frescoes and other decorations of these monuments. For high seismic regions, the retrofit techniques available are: providing reinforced cement coating on wall facing to improve the shear resistance of walls, replacement of masonry wall with new R.C. wall or addition of new shear wall etc. However, these techniques involve more visible intervention and are not suitable for historical buildings.

STRUCTURAL CONTROL CONCEPT FOR RETROFITTING

Seismic retrofitting of historical buildings can be viewed in the light of two major aspectsof earthquake resistant design i.e. *Demand* and *Capacity. Demand* is the expected seismic input to the building, whereas *Capacity* is the resistance of building to meet the demand. The capacity based retrofit strategies include seismic strengthening and can be used for historical buildings if the preservation aspectdoes not destroy. An alternative approach is to reduce the demand on the structure (i.e. earthquake forces and their effects) by modifying the structural properties such as mass, damping, stiffness etc. hence preventing the damages. Also, the seismic strengthening of structurally controlled buildings is either not required or can be done with least visible interventions. *Structural Control Methods* fall under this category and have become much attractive for seismic retrofitting of historical buildings. For the last three decades, various structural-control concepts have been investigated and implemented [Singh M.P., & Liu S.C., (1994), Datta T.K., (1996)]. *Structural Control Methods* can essentially be divided into active and passive control.

The concept of *active control* is relatively recent and its application is mostly limited to design of new structures. In 1972, Yao, first formally introduced the concept of active control to civil engineering [Yao J.T.P., (1972)]. In active control, a control force is applied to the structure by some external energy source, depending upon the expected level of structural response. The control force follows a control law [Soong T.T., (1988), Suneja B.P. & Datta T.K. (2000), Datta T.K., (2003)]. In the *passive structural control,* energy devices

are introduced into the structure to absorb energy. These devices are activated by structural motion and thus, do not require any external force to activate the control. Three basic approaches of passive control are *Base Isolation, Energy Dissipation and Tuned Mass Dampers (TMD).*

BASE ISOLATION AS SEISMIC RETROFITTING OF HISTORICAL BUILDINGS

Among all the methods of structural control, base isolation has gained much popularity for retrofitting of historical buildings. The main concept of base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy containing frequency of excitation. The application of base isolation system into the building reduces the seismic load and their effect by interposing a flexible layer between the foundation and the building. These flexible pads are called as *base-isolators* [Jangid R.S. & Datta T.K., (1995), Vasant A.M. & Jangid R.S., (2008)]. Various types of base isolators that have been frequently used are shown in Fig. 2 [Bandal R.V. & Khandare B.P. (2020), *pp.3]*.

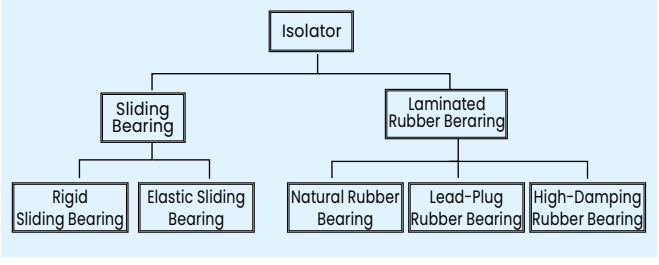

Fig. 2: Types of Isolation Devices (Ref. 16, pp. 3)

Among these, *High Damping Rubber Bearing* (HDRB) *and Lead Rubber Bearing* (LRB), shown in Fig. 3 [Datta T.K., (2003), pp.2] are more popular because of their simplicity in design and implementation.The HDRB (also known as *Laminated Rubber Bearing)* has alternate layers of rubber pads and steel plates bonded together with a robust, non-degrading adhesive. The steel plates prevent the rubber pads from excessive bulging at their perimeter, and hence enhance vertical stiffness of the device. The LRB (also known as *N-Z base isolation system)* has a centrally placed lead plug, which serves as dissipating energy mechanism and thus reduces lateral displacement of isolator.

HDRB LRB

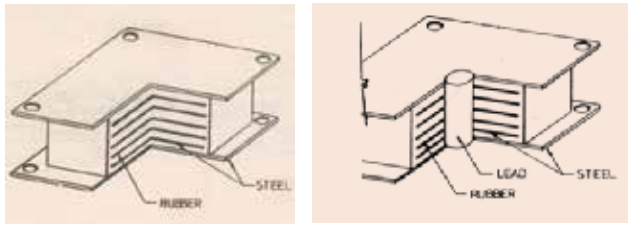

Fig. 3: Laminated Rubber Bearing Base Isolators *(Ref. 13, pp. 2)*

General characteristics of seismic isolators to effectively achieve the goals of base-isolation are:

(i) High axial stiffness to resist vertical loads without excessive deformation

(ii) Sufficiently low horizontal stiffness to substantially reduce the fundamental frequency of the isolated structure in lateral direction

(iii) An effective mechanism for energy dissipation (e.g. damping) to mitigate excessive lateral deformations which might cause instability.

Base-isolation Concept: Base isolation devices consist of flexible bearing supports that are capable of safely supporting the gravity load. Conceptually the idea is very simple, as shown in Fig. 4 [Bandal R.V. & Khandare B.P. (2020), pp.101]. During earthquake when the ground shakes, these flexible isolators deflect safely in lateral direction and very little forces are transmitted to the structure. Basically, isolators reduce the fundamental frequency of the isolated-structure in lateral direction (i.e. lengthen the T, 2 to 3 times) and bring the structure out of the typical frequency-range of seismic inputs as shown in Fig. 5 [Saiful Islam A.B.M. et al. (2011) pp. 101]. The first lateral mode of vibration becomes almost like a rigid body which moves above the isolating interface. The robust medium-rise masonry or reinforced concrete buildings particularly, resting on hard soil strata, are the good candidates (e.g. historical buildings) for effective base-isolation due to their high stiffness. Installation of base isolators in a building is typically shown in Fig. 6 [Murty, C.V.R. (2005), pp. 48].

Challenges/ Limitations: Selection of an effective isolation strategy for retrofitting of historical building requires a sound understanding & vast knowledge of the structural characteristics

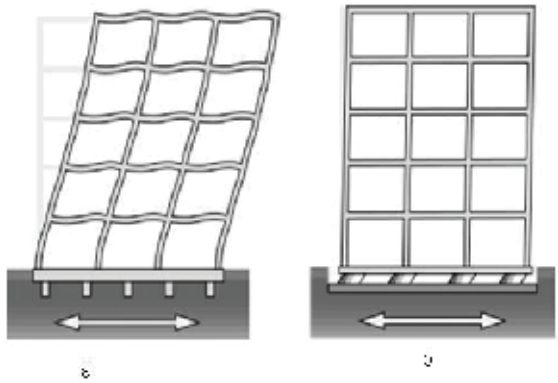

Fig. 4: Basic Concept of Isolation *(Ref. 17, pp. 101)*

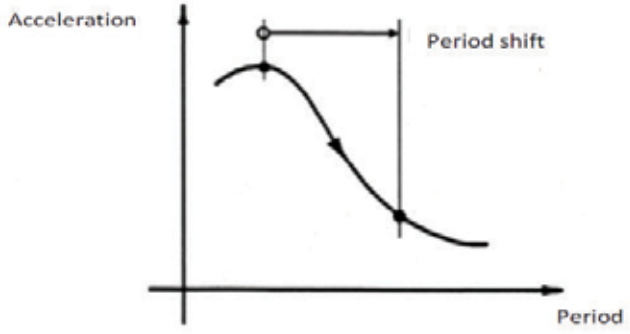

Fig. 5: Period Shift in Base isolated Structures *(Ref. 17, pp. 103)*

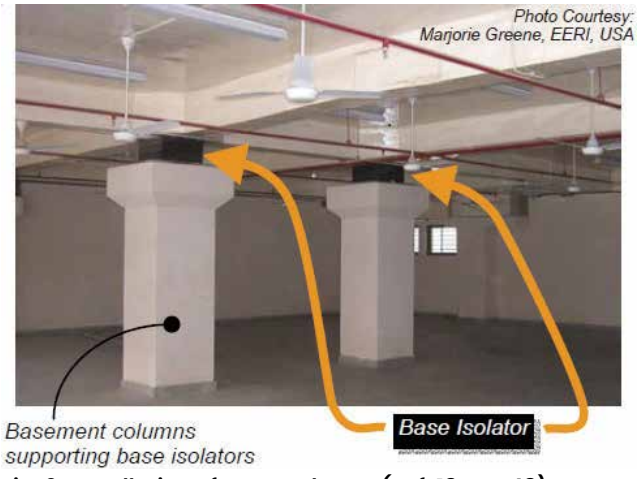

Fig. 6: Installation of Base Isolators *(Ref. 18, pp. 48)*

and expected behaviour of such complicated structures so as to develop the compatible mathematical model. Likewise, some other limitations/ challenges for using the isolation system as retrofitting strategy are:

- Possibility of permanent offset after an earthquake.
- Provision of gap (moat width) to accommodate the lateral displacement at isolation level.
- Not much useful for very tall structures and buildings on soft soil.
- Require highly skilled workers and experienced professionals that involves huge cost.
- In absence of rigid diaphragm at GFL, installation process is cumbersome for historical buildings.
- Stability of isolated structures under normal loading condition must be ensured.
- Selection of type of isolator and its location for installation needs great care as the effectiveness of isolation system is mainly governed by them.

CONCLUSION

The structural control methods particularly, the passive control methods are proved to be good candidates for seismic retrofitting of historical buildings. Base isolation is essentially suitable for seismic protection of historical buildings because any sort of intervention is typically done at the foundation level. The isolators are placed at foundation level and can be replaced if extensively damaged. As the base-isolation leads to the large reduction in seismic forces with least visible intervention, it is often possible to avoid the major reconstruction while using fixed base retrofitting thus, restoring the historical significance of the building. Basically, inter-storey drift & floor-acceleration are mainly responsible for seismic damages of the buildings. It is not possible to reduce both the parameters simultaneously by any of the conventional strategy whereas due to dynamics of base isolated structures it is possible to achieve both these aspects. This prevents the structural and non-structural damages of the building.

Despite the successful application of this technique there is still a hesitation for using base isolation for retrofitting of historical buildings. This is mainly due to the lack of specific codal provisions for repair of historical buildings; an inherent resistance by the engineering community to innovative control techniques and lack of coordination between archeologists and civil engineers. Taking into consideration the fact that these structures need to be preserved for future generation, the additional

cost of the isolators should not be the deciding factor for their retrofitting. Also, the advantages of using base-isolation for the repair and restoration of historic monuments will certainly put to rest any inhibition or challenges the engineers may have regarding base-isolation technology.

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SMART AND SUSTAINABLE SOLUTIONS FOR RESOLVING URBAN TRAFFIC CONGESTION IN INDIA

Narender Singh* and Dr. Sushma**

Abstract

India is one of the fastest-growing economies in the world, with a rapidly increasing population of around 1.40 billion people. However, this growth comes with its own set of challenges, and one of the most crucial is the urban traffic congestion. As more people move to urban regions in search of better livelihood and lifestyle, the number of vehicles on the road has increased dramatically, leading to traffic congestion. Traffic noise and traffic-related air pollutants co-exist in the traffic environment. Polluted air from vehicles contributes significantly to air quality problems through vehicle emissions, which have various harmful impacts on public health. To mitigate traffic problems, focusing on sustainable solutions that consider long-term planning is essential instead of running behind short-term fixes. While short-term solutions (such as road widening, temporary parking & flyover) may provide immediate relief, they may not be sustainable in the long run and can create additional problems too. Long-term planning should focus on reducing the need for cars on the road and improving public transportation systems. Integrated transport networks that provide efficient and affordable public transport options (such as buses, trains, and metros) should be developed. Moreover, promoting carpooling, non-motorized transport options (such as walking and cycling) can also help to reduce urban traffic congestion. In addition to improve the public transport, long-term planning should also focus on developing mixed-use neighborhoods where residents can live, work & play in the same vicinity and can reduce the need for long commutes and car usage.

INTRODUCTION

The rapid migration of people towards urban areas is contributing more and more vehicles on roads, which ultimately leads to congestion. Traffic congestion occurs when vehicles travel at a slower speed because there are more vehicles than the road can handle. This makes travel time longer, slower the speed and increase the vehicular queuing (Fig. 1). This is also known as traffic jam.

Congestion involves queuing, slower speeds and increased travel times, which indeed impose costs on the economy and generate multiple impacts on urban regions and their inhabitants. Congestion also has a range of indirect impacts such as the marginal environmental and resource impacts, impacts on quality of life, stress, safety as well as impacts on non-vehicular road space users.

A recent study by TomTom Traffic Index has shown that Bengaluru, India's leading IT city, is the world's second most traffic-congested city. For instance, to travel a distance of 10 km within Bengaluru city limits, it takes close to 30 minutes, whereas the same distance can be covered in less than 13 minutes in Dubai, however, Bengaluru is not alone in facing this problem, as other major Indian cities also suffer from severe traffic congestion. The impact of traffic congestion is wider than wasted time and frustration for commuters. It also has severe economic and environmental consequences. Traffic jams can increase fuel consumption and emissions, contributing to air pollution and climate change. Furthermore, the time lost in traffic can result in reduced productivity and increased business costs.

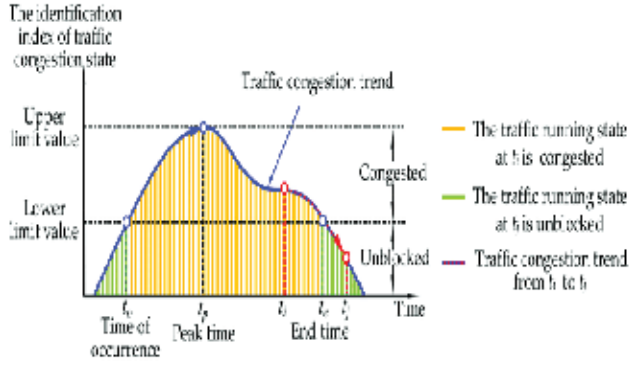

Fig. 1 : Traffic Congestion Trend

** Superintending Engineer, PWD (B&R) Haryana*

*** Assistant Professor, Department of Chemistry, Government College Hisar, Haryana*

TYPES OF TRAFFIC CONGESTION

There are different types of traffic congestion as given below:

- **Recurrent Traffic Congestion:** Regular traffic patterns are the root cause of this form of congestion, which happens around specified periods of the day, such as rush hour. It is foreseeable and frequently manageable with the right traffic management techniques.
- **Non-recurrent Traffic Congestion:** This kind of traffic jam is erratic and can be brought on by mishaps, road closures, or bad weather. It is frequently challenging to control and can result in lengthy delays for cars.
- **Phantom Traffic Jams:** Phantom traffic jams happen when a minor disruption, such a car braking quickly, sets off a cascade of brakes that moves traffic backward. Even if there are no physical barriers on the road, this might force traffic to slack off or stop altogether.
- **Bottleneck Traffic Jams:** When transportation is slowed down by physical obstacles like congested intersections, joining lanes, or traffic lights, bottlenecks happen. Traffic may sluggishly slow down or stop altogether as a result of this.
- **Incident-related Traffic Congestion:** When a collision, mechanical issue, or other occurrence on the road affects traffic flow, there is this kind of congestion. Drivers may experience lengthy delays as a result, and emergency services may be called to the scene.
- **Work zone Traffic Congestion:** When a roadway is undergoing construction or maintenance, congestion of this kind develops. Lane closures, lowered limits on speeds, and additional traffic control measures may result, which could delay motorists.

SCENARIO OF MOTOR VEHICLES GROWTH IN INDIA

The automotive vehicles are increasing drastically due to increase in population, urbanization and change in our life style. As mentioned in "Road Transport Year Book 2019-20, Ministry of Road Transport & Highways", the total number of registered motor vehicles increased from 0.30 million as on 31st March, 1951 to 326.29 million as on 31st March, 2020 (Fig. 2).

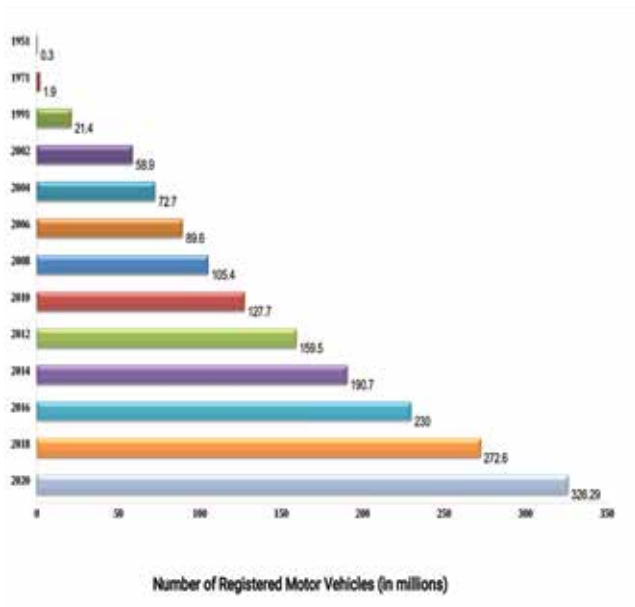

Fig. 2: Number of Registered Motor Vehicles in India (in millions)

In India, the total number of registered buses were 11.10% in 1951and 0.07% in 2020 as shown in table 1. This drastic decline clearly reflects that we prefer 88.10 % personal vehicles (two wheelers, cars, jeeps, etc) than the public transport which ultimately leads to traffic congestion and also spoiling the environment.

PETROLEUM PRODUCTS CONSUMPTION IN INDIA

In India, the increased growth of vehicles, gave exceptional hike in consumption of petroleum products. As mentioned in "Annual Report 2022-23, Ministry of Petroleum & Natural Gas", the total petroleum product consumption has increased from 111.60 MMT in 2004-05 to 214.13 MMT in 2019-20 (which is almost doubled in last 15 years) as shown in Fig. 3.

This increase in consumption of petroleum products will result in steep rise in their demand and make it difficult for government to subsidize

Table 1 : Composition of Registered Motor Vehicles in India (% of total)

Composition of registered motor vehicles in India (% of total)						
As on 31st March	Two Wheelers	Cars, Jeeps etc.	Buses	Trucks	Other Vehicles	Total (Million)
			(as % of total motor vehicle)			
1951	8.8	52.0	11.10	26.8	1.30	0.30
1971	30.9	36.6	5.0	18.4	9.10	1.9
1991	66.4	13.8	1.5	6.3	11.9	21.2
2002	70.6	12.9	1.10	5.0	10.4	58.9
2004	71.4	13.0	1.0	5.2	9.4	72.7
2006	72.2	12.9	1.1	4.9	8.8	89.6
2008	71.5	13.2	1.4	5.3	8.6	105.3
2010	71.7	13.5	1.2	5.0	8.6	127.7
2012	72.4	13.5	1.0	4.8	8.3	159.5
2014	73.10	13.60	1.0	4.60	7.70	190.70
2016	73.50	13.10	0.80	4.60	8.10	230.00
2018	74.40	13.37	0.71	4.69	6.85	272.60
2020	74.70	13.40	0.07	4.40	6.90	326.29

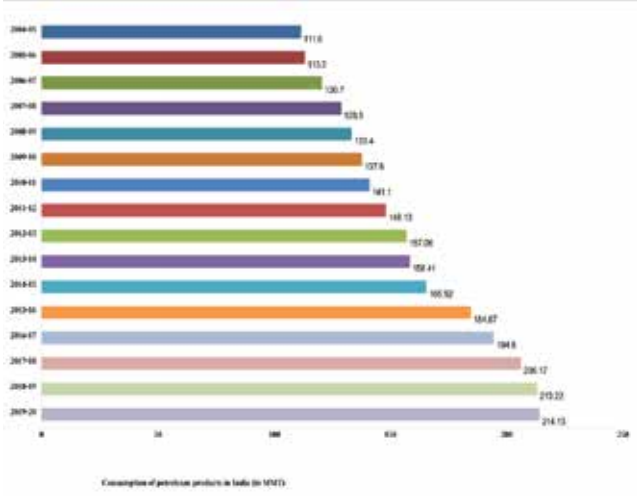

Fig. 3: Consumption of Petroleum Products in India (in MMT)

petroleum products in future. It's the need of hour that we should adopt smart and sustainable public transport to curtail the growing demand of petroleum products and also safeguard the environment.

CAUSES OF TRAFFIC CONGESTION

The main causes which are responsible for the urban traffic congestion/ jam are given below:

- **Lack of adequate public transportation:** People are encouraged to look for and spend in private transport due to the lack of adequate public transport. For instance, Bengaluru is infamous for its traffic congestion, which is mostly related to the lack of adequate public transportation. Thus, the majority of people purchase a personal vehicle, further clogging the roads.
- **Maintenance and construction:** Sometimes, traffic congestion can be caused simply due to construction or maintenance work which may lead to lane closure which causes heavy traffic.
- **Poor traffic discipline:** Indian drivers frequently disregard traffic laws, which cause tense situations on the road. As a result, there is a lot of traffic congestion and a lot of traffic accidents.
- **Roadside sellers and encroachments:** Roadside sellers frequently erect their businesses alongside the road, limiting room for cars and clogging up traffic.

- **Excessive use of cars:** Traffic is also caused due to the presence of too many cars on the road. India's population is growing, and traffic jams happen when there are more cars on the roadways than there are spaces for them to travel. For those who use an identical congested route to and from work every day, it is a persistent issue. It happens when a city's population increases more quickly than its infrastructure.
- **No staggered hours for traffic:** No staggering of office and school hours is being provided by local authorities who also cause traffic congestion during peak hours.
- **Accidents due to improper weather conditions:** Travellers' nightmares include poorly built roads and poor drainage, particularly during the monsoon season. Long traffic delays can result from even small collisions when oncoming traffic slows down to witness the incident and emergency vehicles arrive on the site.
- **Lack of parking space:** Due to insufficient road capacity and lack of parking space in urban regions, the congestion occurred often.

EFFECTS OF TRAFFIC CONGESTION

Slower speeds, lines, and longer travel times are all symptoms of congestion, which raises economic expenses and has an effect on metropolitan areas and the people who live there. Indirect effects of congestion include those on the standard of life, stress levels, and safety, as well as effects on users of non-vehicle zones including those who use pavements and properties along roads. Congestion also has a variety of direct effects. The impacts of traffic congestions are given below:

- Congestion simply represents a loss of time and resources. The time lost in traffic could be productively utilized to complete some tasks.
- The abrupt stop-and-go driving style in congested areas increases the consumption of fuel in the city, which raises the pollution level by releasing additional carbon into the atmosphere.
- The slow-moving traffic also causes some hydrocarbons and nitrogen oxides to be released, which is the main cause of what is known as photochemical smog.
- Traffic congestion produces loud noise (over 90 dB), which makes the atmosphere uncomfortable. The regular traffic congestion leads to emission of various pollution causing gases and spoil the eco-system and further cause health problems as shown in Fig. 4.

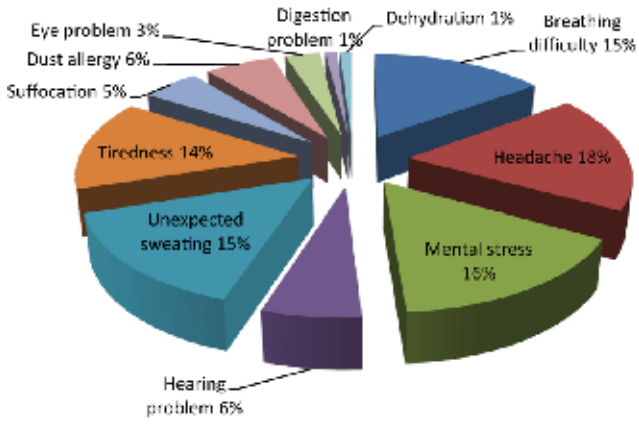

Fig. 4 : Health Problems due to Traffic Congestion

Due to traffic congestion, various businesses may lose money because of increased fuel costs, driver's wages and vehicle servicing due to increased travel time.

SMART & SUSTAINABLE SOLUTIONS TO RESOLVE THE PROBLEM OF CONGESTION

To cope up with the problem of traffic congestion, both the short term as well as long term measures needs to be implemented as discussed below.

Short Term Solutions

The short term measures can help to avoid traffic congestion with immediate effect, but not sustainable for the long run. These measures are as under.

- **Strict lane management:** The roads should be marked with various lanes for different types of vehicles, and the legislation, i.e. a financial penalty, should be applied to force drivers to keep the lane discipline.
- **Implement traffic management techniques:** Congestion pricing, round abouts, and traffic signals are some examples of traffic management techniques that can help to manage traffic flow and ease the congestion.
- **Expansion of road networks:** Increase

capacity of road networks by adding new roads and extending existing ones to assist relieves traffic congestion.

- **Enforcing the traffic rules and putting tax on parking:** These measures will also help to reduce traffic congestion up to some extent.

Long Term Solutions

Long term measures are essentially required to be implemented by public authorities for the sustainable development. These measures are as under.

- **Improved urban planning integration:** Currently, the country's city municipalities control the policies governing urban transport. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM), an initiative of the Indian government, was given the national mandate to modernize urban areas, notably urban transport. States and municipalities are expected to enact changes in urban development regulations, which relate to the management of money and adoption of new legislation pertaining to the urban land ceiling and public discourse law, among other things, to receive funding under this program.
- **Improving public transport:** The number of cars on the road can be decreased by developing smart, efficient, affordable and integrated public transport networks of buses, trains and metros. Smart transportation is a network for industry and services, which acts as an engine & catalyst for growth and prosperity. Several dimensions of sustainable development may benefit from an improved transportation system. Clean and highly eco-performing public transport can be the backbone of sustainable urban transport services. Public transport represents an acceptable alternative to cars, only when it is safe, clean, reliable, fast, frequent, noiseless, flexible, easily accessible, well designed, environment friendly and economically viable. A smart transportation system allows for an integrated view of real time traffic data through the use of devices installed on roads such as traffic signals, cameras and sensors (Fig. 5). This data is processed with the purpose to establish an intelligent and adaptive traffic management system that empowers drivers through dynamic messaging and other methods, to choose optimal routes and avoid accidents or street problems, thereby increasing safety and curtail the traffic congestion to the optimum extent.

Fig. 5: Smart Transportation System

- **Promoting carpooling and non-motorized transport options:** Promoting car pooling and non-motorized transport options (such as cycling and walking) also helpful in traffic congestion reduction.
- **Developing mixed-use neighborhoods:** In addition to improve the public transport, long-term planning should also focus on developing mixed-use neighborhoods where residents can live, work & play in same vicinity and can reduce the need for long commutes and car usage. For example, Mahindra World City in Chennai is a mixed-use development that combines residential, commercial & industrial zones, reducing need for residents to commute long distances for work or leisure (Fig 6). It is India's first integrated business city developed by Mahindra Group & TIDCO based on public private partnership. Such developments reduce traffic congestion & prove eco-friendly too.

CONCLUSION

The automotive vehicles are increasing rapidly due to increase in population, urbanization and change in the life style of human which ultimately lead to traffic congestion. It is the need of the hour that we should promote smart and sustainable measures including public transport

than personal vehicles to deal with the problem of traffic congestion and safeguard our health and environment.

Fig. 6 : Mahindra World City, Chennai

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CHALLENGES FOR HERITAGE STRUCTURE CONSERVATION

Srikumar Bhattacharya*

Abstract

Heritage structures are age old structures with historical value along with architectural importance. These heritage structures are at stake due to demolition and coming up of new construction and also due to long pending repairs and maintenance. Mostly the structures are masonry type with lime mortar and arch type of construction. Due to passage of time these structures are badly affected and damaged and the bonding becomes loose in masonry. In some cases vegetation is growing on the surface of masonry structures forming cracks and disintegration of the structure.

The old structures are in some cases carrying more loads than their capacity, which need to be strengthened. The structures may also be damaged due to wind or earthquake, which have to be retrofitted. The challenge for the conservation of heritage structure are lack of awareness, non-availability of experienced labour and contractors in the field, litigation due to change of owners and non-availability of appropriate materials.

INTRODUCTION

Heritage structures are of special importance due to their historic values and architectural importance. It has relation with our cultural heritage, personality and or special architectural values. Due to rapid development these heritage structure are in danger and being damaged by weathering and due to growth of vegetation. Conservation of these structures is a challenging task due to lack of awareness, experience and non-availability of suitable materials and skilled labours.

HISTORY OF CONSERVATION

In 3rd century BC Ashoka passed order to conserve wild life which is the 1st conservation attempt in India. Later on in 14th century Firuz Shah Tughlaq had taken action to protect ancient buildings. Subsequently in British period Bengal Regulation (XIX) was passed in 1810 and also Madras Regulation (VII) in 1817. Archaeological Survey of India was established in 1861 for legal protection of historical structures in India. Ancient monument preservation act (VII) was passed in 1904 to preserve the monuments. Under the West Bengal Act IX of 2001 West Bengal Heritage Commission had been established as the authority of heritage structure in West Bengal.

GRADING OF HERITAGE STRUCTURES

Heritage structure is graded in three types namely Grade I, II and III according to its architectural importance historical values and age of construction. Grade I structure is the most important National one to preserve strictly and less important is Grade II Regional and lastly are local Grade III. Normally no addition and alterations are permissible in Grade I structures for Grade II structures of Type A external change are not permissible but internally can be changed intelligently but for less important Type B structures changes are permissible in the premises. Grade III structures can be suitably changed in consultation with the authorities.

FACTORS DAMAGING HERITAGE BUILDINGS

There are two main factors which are responsible for the damage of old heritage structures and these are Natural and Social factors. Natural factors are due to natural disasters and in the way of natural decays due to Flood, Rainstorm, Windstorm, Lightening, Air pollution, Earthquake, Biological growth and Temperature variation due to Extreme climate etc. Social factors are manmade and are due to Fire, Urban Development, Deforestation, Vandalism and Terrorist activities etc.

CONSERVATION TECHNIQUE

Conservation and preservation techniques for built heritage are of two nature - one Structural Conservation, and the other Chemical Conservation. The age old heritage structures are of masonry structures as at that time RCC was

Former Engineer-in-Chief & Ex Officio Secretary, PWD, Govt. of West Bengal

not introduced and cement was not available so mostly lime surki mortar or stone dust were widely used with clay bricks or stone blocks for bonding. Due to passage of time for weathering effectthe bond is loose and for which bricks or stones are disintegrated causing structural damage. Structural conservation is basically restoring the structure in previous position using same materials as used originally. Chemical Conservation is basically the chemical treatment of the Built Cultural Heritage for preventive action for any further loss of arts in script on the structures.

RETROFITTING

It is the technique by way of which the existing structure can take more load as per existing condition. The method is generally followed for any type of load which was not considered at the time of planning and construction. Mostly earthquake load is often missing in old structure for which retrofitting of the existing old structure is essential to make the structure more strong.

CASE STUDIES

Some old Heritage buildings are taken up by PWD, Government of West Bengal and are successfully being conserved out of which namely Writer's Building, Kolkata Town Hall, Kolkata High Court and Garh Panchakot are good examples for recent works.

- **Writer's Building:** This Building was constructed in 1777 as the sadardaftar of British East India Company and afterwards was the secretariat building of the West Bengal Government and now under restoration. Thomas Lyon was the Architect of this Gothic Structure (Fig.1). Due to East west metro corridor passing very near to the old structure and due to its underground construction activities strengthening of the age old structure and its proper retrofitting planned. As per planning the topmost floor roof was dismantled and reconstructed with RS Joist and RCC composite type. The masonry walls are tied up and strengthened by lacing steel joist and embedded inside so that it acts as an integrated structure(Figs. 2 & 3).

TOWN HALL, KOLKATA

- **Town Hall:** The British Architect Colonel John Garston started to construct in 1807 for the hosting of social gatherings of the Europeans with Doric style of architecture (Fig. 4). The structure was in danger for earthquake and for which it was retrofitted for earthquake forces in consultation with IIT, Roorkey (Figs.5& 6).

Fig. 1: Writer's Building, Kolkata

Fig.2: Retrofitting works at Writers Building, Kolkata

Fig.3: Retrofitting works at Writers Building, Kolkata

- **Kolkata High Court:** Constructed in 1862 in

Fig.4: Town Hall, Kolkata

Fig. 5: Restoration work of Town Hall, Kolkata

Fig.6: Restoration & Retrofitting works in Town Hall

Neo Gothic style of architecture, the oldest High Court of India, inspired by Belgium's State House architect was Mr Walter Granville (Fig.7). A part of floor of 1st floor suddenly collapsed on 17th September 2018 and urgent restoration wanted (Fig.9). Due to uneven settlement of a part of structure cracks at different floors are

Fig. 7: Kolkata High Court, Kolkata

Fig. 8: Micro piling works for stabilisation of soil movement

Fig. 9: Collapse of 1st floor

appeared and in consultation with Prof. Mittal of IIT Roorkey Micro piling works along with grouting had undertaken (Fig. 8).

- **Garh Panchakot:** Garh Panchakot has the potential to become an important cultural destination. Meaningful narrative of its Historic legacy of more than four centuries – 'Shakta' movements, 'Vaishnava' movements, folk traditions anchored in these historic settings, buildings and landscape provides a unique experience. The restoration of Gates at Ranimahal already done (Fig.11) 7 also the temple structure (Fig.10).

Fig.10: Garh Panchakot Kolkata Temple, Arch inside

Fig. 11: Restoration of Gate at Rani Mahal Garh Panchakot

CONCLUSION

Very few conservation architects are available at local level as well as skilled labour are also not available. Scarcity of some materials for bonding like lime mortar etc is also challenge for the restoration. The items of restoration works need separate exclusive schedule of works with special rate considering every detail of work with utmost care and not as a routine maintenance like job.

WAY AHEAD: There are many heritage structures throughout our country which need immediate attention and lot of fund is also required. Apart from execution of work general awareness is very much essential to protect the structures in right time. Proper skilled labour with dedication to such work is also a major challenge for restoration work.

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PREFABRICATED HOLLOW BLOCKS FOR AFFORDABLE HOUSING

V. Srinivasan*, D. Girish Kumar, S. Sundar Kumar* And V. Ramya*****

Abstract

Population growth and Industrial development, there is general shortage of housing and building materials. The housing industry is a fundamental and strategic sector linked to improve the living standard. The problem of housing for the urban dwellers is increasing day by day due to increase in the land price and building materials. The conventional construction techniques, due to slow pace of construction and higher cost, is not able to meet the housing demand. In order to fulfil the demand, it is necessary to develop several building materials and prefabricated construction which are not only eco-friendly but also cheap. Since, availability of natural resources is limited. Therefore, there is a need to develop affordable building materials using industrial waste such as fly ash, steel slag, rice husk ash etc. Reducing material wastage as well as environmentally friendly approach will definitely reduce the cost of the house.

Construction sector today has become one of the largest consumers of natural resources and energy in various forms which has become serious concern for sustainable development. Quality, speed of construction and savings in labour and material cost are main features in the proposed housing system. This paper will be an attempt to provide an easy to erect, portable and of reasonable cost using standardized prefabricated housing components. Small hollow panel units of dimension 150 x 450 x 300 mm have been fabricated with 35 to 60 mm thick concrete sections. It is designed on one side as male and other side as female part to give proper connectivity. Rice husk ash (20%) is added as partial replacement of slag cement. The recycled aggregate is used as a replacement for the natural coarse aggregate. The recycled aggregate is added in the ratios from 25%, 50% and 75%. The concrete is prepared in different ratios by replacing coarse aggregate with recycled aggregate for the standard mix design and its workability by slump cone test. This makes it possible required strength and reducing its cost. Urban housing can be successful if they are rooted in the community, present innovative solutions to real problems, enable others to imitate it.

INTRODUCTION

Shelter is one of the basic necessities of human life as well as an essential component for social economic development. A certain minimum standard of housing is essential for health and civilized existence. Housing for all is an important national agenda of the Government of India.

The central and state government have undertaken a number of initiatives to address the situation with serious challenge in urban area. Housing creates a strong ground for hygienic and healthy life. Construction industry is one of the main sectors that provide significant ingredients for the development of an economy. The construction industry in India is moving towards prefabricated method of construction in order to meet the huge demand for housing and better quality control at affordable levels. The duration of construction plays a very vital part in this regard. However, the housing problem continues to be acute because of the explosion of population, the rising cost of building materials, and labour. A change in social economic patterns from traditional agriculture to manufacturing industry has changed planning patterns and construction system in urban areas. In fast growing urban areas, the gap between demand and supply of housing is continuously increasing.

Now-a-day, the construction sector has become one of the largest consumers of natural resources and energy in different forms which is become a serious concern for sustainable development. The rapid urbanization and civil infrastructure development are looking for a faster construction technology having economical and environment-friendly construction system. There is a mismatch

** Principal Scientist, Advanced Materials Laboratory, Structural Engineering Research Centre, Chennai*
***Project Student, Government College of Engineering, Thanjavur, Tamil Nadu*
****Assistant Professor, Government College of Engineering, Thanjavur, Tamil Nadu*

between the demand and supply of urban housing due to escalation in material cost and construction practices.In order to minimize the time span of the construction and maintain the quality in construction, prefabricated system is generally preferred.The availability of building materials for construction industry is very limited. All principal materials like cement, steel, brick stone aggregate etc. are having shortage. The extensive use of quarrying have lead to environmental degradation. Hence, need has been felt to promote alternative building materials by recycling Construction and demolition (C & D) waste and use the existing materials more efficiently.

Construction and demolition waste (C&DW) accounts for largest percentage of waste generation in the world (Clark et al., 2006). Kibert (2016) highlighted that around 50% of this waste is due to end of life activities i.e. primarily demolition. Demolition waste are disposed either is construction and demolition debris landfills or solid waste landfills demarcated by different governmental bodies in different countries. Disposing the waste in landfill is the end-stage of a typical linear construction approach, (Nasir et al., 2017). This underline the basis of urban mining concept, which represent technologies and actions used towards recovering secondary usable raw materials from products of urban catabolism (Baccini and Brunner, 2012). Brunner (2011) highlighted that anthropogenic materials from urban spaces can be cyclically used, recycled and reused.Recycled coarse aggregate obtained from concrete demolition waste has been proved to be alternate source of aggregates for new concrete production. There are many studies that prove that concrete made with this type of coarse aggregates can have mechanical properties similar to those of conventional concretes. However, limited studies have been reported in literature for the use of fine fraction of C & D waste in prefabricated building construction. As a result, a proper mix design is required for obtaining the desired qualities for concrete made with recycled aggregates.

The recycled material is defined as a material which can be remade and reused as a building material after the building is demolished. It is called recycled when the building product partly or totally manufactured from the disassembled materials. The method of processing recycled material can be classified into three types. Product recycle, material recycle & feed stock recycled. Production recycle refers to a process where the product can be used again, with out changing the form / nature of the materials. Material recycle is a process that after it is separated / collected, the disassembled material is processed in to a building material. Feed stock recycle, refers to a process where the disassembled material is processed into feed stock to make a building materials (CIB, 2013). In India, C& D waste generated an environmental, social and economic challenge. The objective is the recovery through recycling of C & D waste in the production of construction materials in order to minimise the environmental impact in urban area. Nowadays, attention has been paid to recycling with in the building sector in several ways. Guidelines and standards have been introduced that will indirectly, promote increased recycling. Natural graded granular materials are conventionally used as a fill material for various civil engineering applications. Table 1 shows the Construction and Demolition waste generation in selected Indian Cities. Application of RCA concrete has been slow primarily because of apprehensions that concrete containing RCA might be inferior to concrete made with natural coarse aggregate (NCA).

PROPERTIES OF RECYCLED AGGREGATES

The amount of mortar that remains attached to the recycled aggregate (RA) various for different sizes of aggregates. Higher percentage is for the smaller aggregate size. If this mortar could be removed, the properties of recycled aggregate should be the same as that of original aggregate, But this process is time consuming and also makes its use uneconomical. The properties of fresh and hardened concrete depend on the particle shape and surface texture. Normally the article shape of the recycled aggregate is more irregular than conventional aggregate and has coarser surface. The specific gravity of the recycled aggregate is cover than the corresponding conventional aggregate and water absorption is higher, due to the presence of low density porous mortar (Srinivasan & Singh). The properties of recycled aggregate

Table 1: Construction and Demolition Waste generation in Indian Cities

City	Population in Million (Census 2011)	Daily CDW generation (Tonnes / day)	Annual CDW generation* (Million tonnes / annum)
Mumbai	12.44	2,500	0.75
Delhi	16.79	4,600	1.38
Bengaluru	8.44	875	0.26
Chennai	6.50	2,500	0.75
Kolkata	4.50	1,600	0.48
Jaipur	3.47	200	0.06
Patna	2.52	250	0.08
Ahmedabad	6.06	700	0.21
Bhopal	1.92	50	0.02
Coimbatore	2.62	92	0.03

Source : Ministry of Housing and Urban Affairs, 2018

**Daily generation has been multiplied by 300 to calculate annual generation*

depends on the method of recycling adopted like crushing manually or using a jaw crusher.

C & D WASTE MANAGEMENT

Management of C&D waste is still a challenge for urban local bodies. Most cities do not have formal demolition permits and developers hire local contractors for demolition. Even government agencies like PWD invite bids for demolition based on what contractors would pay for recoverable. The recoverable of immediate secondary market value, such as metal rods, pipes and fixtures, wooden frames, etc., are salvaged by the informal sector, typically from demolition sites, leaving behind the "rubble" composed of bulky materials such as concrete, stones, bricks and mortar, etc. A small fraction of this rubble is used for back-filling in construction projects, both for private projects and public works, and the same demolition contractors arrange for its transportation to sites where it is needed. It is estimated that such uses may account for only 10-30% of generated C&D waste depending on the site and region. The remaining fraction of C&D waste is disposed, either in designated landfills/dump sites or often in unauthorised places such as road sides, river beds and low-lying areas causing a host of nuisance, safety and environmental problems.

TREATMENT METHODS

In order to improve the quality of RA, several techniques have been developed in published literature (Bhashya and Bharatkumar, 2022). The waste generated during the dismantling process have potential to be recycled as raw materials to reproduce building materials or other products. However, these methods can be broadly categorized into two categories. The first category removes the loose mortar particle on the surface and the second category modifies the aggregate surface (Torgal et al., 2013). Mortar removal, is a vital technique, which could produce RCA with similar morphology & properties to conventional aggregates and also, the same mix design approach (use of RCA in dry condition) could be used, not causing any trouble to the site engineers. All the RCA beneficiation techniques described in this paper require a variety of additional mechanical and thermal processes including heating, rubbing, sieving and conveying, which result in an increase in the overall cost, energy use and carbon footprint of recycling (ICI 2019). The various approaches for the removal of adhered mortar of RCA are outlined in the table 2.

Table 2: Various Approaches for the removal of Adhered Mortar of RCA

Treatment method	Large scale production	AM Removal	Easy of operation	Duration	Remarks
Mechanical rubbing	Yes	Medium	Convenient	Short	• More energy consumption • Multiple stage process
Acid soaking	Not suitable	Low	Operator sensitive	Long	• More water footprint • Long residing time • Issue of handling acid • Contamination of aggregates due to sulphates and chlorides
Microwave Heating	Not suitable	Medium	Inconvenient	Very short	• Arching and fire ball formation in presence of organic impurities • Involves specialized equipment
Conventional Heating and scrubbing	Yes	High	Convenient	Medium	• More energy consumption

EXPERIMENTAL DETAILS

Materials Used

Portland Slag Cement (Brand: JSW) conforming to IS 455 - 1989 was used in the present investigation. The specific gravity of cement is 3.13. Rice husk ash was used as a cement replacement material. Slag cement was replaced at the constant level of 20 % by weight. Locally available river sand passing through 4.75 mm sieve as per IS 383 provisions confirming to zone II were used as fine aggregate. Machine crushed locally available hard granite, well graded 20 mm and down size were used as coarse aggregate. The concrete debris were collected from rigid pavement surface (Chennai) as source and broken into the pieces of approximately 80 mm size with the help of hammer & drilling machine (Fig. 2). Jaw crusher is used for crushing recycled concrete aggregate to produce required size of aggregate (Fig. 3). Conplast SP 430 naphthalene based super plasticizer was used for the workability improvement.

Fig. 2: Collected Recycled Concrete Aggregate (rigid pavement)

Fig. 3: View of Jaw Crusher

Table 3: Quantity of materials as per IS 10262

Materials	Quantity in kg			
	M1	M2	M3	M4
Slag cement	404	323	323	323
Rice Husk Ash	-	80.8	80.8	80.8
Fine Aggregate	746	746	746	746
Coarse aggregate 20 mm (60%)	635	476	317	159
10 mm (40%)	423	317	212	106
Recycled Coarse Aggregate 20 mm (60%)	-	159	317	476
10mm (40%)	-	106	212	317
Water	197	197	197	197
W/C ratio	0.48	0.48	0.48	0.48
Super Plasticizer %	0.5	0.5	0.5	0.5

Note: M1- Control mix, M2- 25% RCA, M3- 50 % RCA and M4 – 75 RCA

SLUMP

The slump of recycled aggregate concrete decreases with increase in percentage replacement of recycled aggregates. Fig. 4 shows the slum test of concrete mixes and indicates that addition of recycled Concrete aggregate reduces the slump of the concrete. Further, decreasing trend for slump of concrete is obvious with an increase in RCA. It is recommended to i) use super plasticizers and ii) use mineral admixtures, in order to overcome the slump loss.

Fig. 4: Slump Test of Fresh Concrete

COMPRESSIVE STRENGTH

The average compressive strengths cubes cast are determined as per IS 516 using natural aggregate and RCA at the age 7,14 and 28 days. Fig. 5 shows the casting of various specimens (cube, cylinder, prism). As expected, the compressive strength of RAC is lower than the conventional concrete made from similar mix proportions. The amount of reduction in strength depends on parameters such as grade of demolished concrete, replacement ratio, w/c ratio, processing of recycled aggregate etc.

Mechanical properties such as compressive strength (Fig. 6), split tensile strength of concrete

mix at different days are shown in Table 4. The compressive strength at 25 % RCA replacement is 33.6 MPa, lesser than that control mix 40.18 MPa. It is noted that excessive inclusion of RCA reduces the compressive strength in all mixes. The split tensile and flexural strength of 25 % RCA mix are 5.53 % and 1.64 % lower than that of control specimens.

Fig. 5: Casting of Various Specimens

Fig. 6: Compression Test of Cube Specimen

Table 4: Mechanical properties of Concrete Specimens

Mix ID	Compressive Strength (MPa)			Split tensile strength (MPa)	Flexural Strength (MPa)
	7 Days	14 Days	28 Days		
M1	24.39	31.93	40.18	3.705	4.516
M2	19.58	27.07	33.6	3.500	4.442
M3	18.19	24.58	28.15	2.992	3.910
M4	16.83	21.71	23.49	2.796	3.885

PREFABRICATED HOLLOW CONCRETE BLOCK

There are many types of hollow concrete blocks which vary with the grade of concrete mix used in the manufacture and based on the dimensions of the block. At present there are no standard blocks consistently manufactured all over India (BMTPC, 2017). The commonly used hollow concrete blocks for compound wall constructions were found to be very poor in concrete quality.

Based on the scientific study and the Indian socio-economic system, it is considered to adopt a technology which is simple in adoption and labour oriented also and easy to understand by the normal construction workers. In the approach adopted a small wall panel system has been taken as a unit which will be called small Hollow Block unit as it will act as a wall panel and will be used as a block in construction. It will also be easy to handle by two persons on site. As per normal construction, the units can be placed as wall with the help of small columns on the functions. Accordingly, the standard housing units can be designed for one and two room units for the EWS and LIG people of the nation where cements and concrete is almost easily available.

Steel mould is fabricated using steel sheet with easily detachable nut and bolt connections. Small hollow panel units of dimension 150 x 450 x 300mm have been conceived with 35-60mm concrete sections in the shape as given in the Fig. 7 having two rectangular holes with larger size on one side, to ease in the production process. It will help to remove the mould to create hollow portions in the panel unit. It is designed on one side as male and other side as female part to give proper connectivity. The concrete mix was placed in moulds and was properly compacted. The hollow blocks were taken out from the moulds and were placed on open space for a week. After one week, when the specimens had attained sufficient strength for handling. Similarly, a half unit has been developed of size 150 x 220 x 300mm having single rectangular hole and same size (Fig. 8) of male and female parts to be used in the construction of wall to avoid the vertical joint and give a proper bond. The weight of the main unit is 30 kg and that of half unit is 13 kg which can easily be handled manually by two and one labour respectively. Compressive strength and water absorption of hollow block units are shown in table 5.

It is observed the reduction in concrete compressive strength of hollow block when the

Fig. 7: Full Size Steel Mould and Hollow Block Specimen (150 x 450 x 300 mm)

Fig. 8: Half Size Steel Mould and Hollow Block Specimen (150 x 220 x 300 mm)

Table 5: Compressive Strength and Water Absorption of Hollow Block

Mix Id	Compressive Strength (MPa)		Water Absorption (%)	
	Full Block	Half Block	Full Block	Half Block
M1	8.62	8.94	2.38	2.16
M2	7.39	7.68	2.89	2.73
M3	6.92	7.12	3.48	3.29
M4	6.65	6.89	4.29	4.12

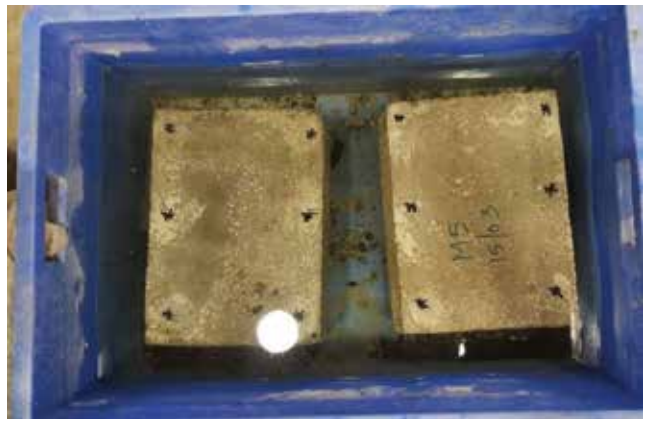

Fig. 9: Water Absorption Test of Hollow Block Specimen

natural aggregate replaced by the recycled concrete aggregates. Technology has developed using rice husk ash and recycled concrete aggregate to produce hollow block for precast buildings. The hollow blocks are normal weight, easy to handle, transport and erect. This offers the following advantages i) For mass housing and affordable housing / buildings; ii) For quality and speedy constructions and iii) Sustainable and green construction through savings in costs. All the hollow blocks tested satisfied A grade of IS 2185 (Part 1) 2005, which can be used as load bearing wall for low rise buildings. Also based on the experimental results obtained on hollow block can be used for partition wall in medium rise buildings. It is relatively lighter in its dead weight. For producing hollow blocks, coarse aggregate was partially replaced with RCA to reduce the cost. There are practical construction difficulties in reinforcing the conventional solid brick masonry. Hence, the ideal solution would be to reinforce the hollow concrete block masonry (lost formwork)

CONCLUSION

The approach of prefabricated building system is very eminent in view of the rapid increase in urbanization and economic growth. The current scenario speed, quality, and economy of construction are the issues of urban housing. An attempt has been made in this paper to discuss present status, different technologies, issues, advantages and disadvantages of prefabricated construction in India. Though there are several advantages of using prefabricated technologies, it is not widespread in India till date except in few states for the government projects. The major issues are lack of proper guidelines, awareness

and skilled labours. It is evidenced low cost and quality conforming than in-situ construction. The research and academic institution should come forward to evaluate completely prefabricated systems to evolve-standards / guidelines and design approach. Thus, it is an urgent need to improve the standardization and prefabrication along with customization with adequate training of the stakeholders (architects, builders, engineers, contractors etc.).

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WASTE SEGREGATION : A PSYCHOLOGICAL EXPLORATION

Harsh Gupta*, Vara Prasad Kasa, Dr. Bharath H. Aithal*** and Dr. Brajesh Kumar Dubey******

Abstract

Municipal Solid Waste management poses a significant challenge globally, with complexity in rapidly urbanizing countries like India. Despite legislative frameworks and various waste management initiatives, effective waste segregation at the source remains elusive. This study investigates the underlying factors that influence the behavior of waste segregation among residents of Jamshedpur, India. Drawing from a sample of 537 respondents, the study utilized a Likert-scale questionnaire to explore both external and internal factors that impact waste segregation practices. External factors encompass government policies, incentives, and infrastructure, while internal factors include personal attitudes and perceived behavior control. Demographic analysis reveals insights into gender distribution, age groups, and income status. The results indicate a strong inclination towards waste segregation among the respondents, with 91% expressing interest. Moreover, a significant majority (77%) are willing to pay penalty fees for improper waste segregation, signaling potential receptivity to policy enforcement measures. The study highlights the critical role of efficient waste segregation in addressing India's growing waste management challenges amid rapid urbanization. By elucidating the complex dynamics that influence waste segregation behavior, this research aims to inform policy interventions and foster more sustainable waste management practices in India, ultimately contributing to global efforts toward environmental conservation and resource sustainability.

INTRODUCTION

The rapid growth of India's urban population, coupled with urbanization and industrialization, has significantly strained the management of Municipal Solid Waste (MSW) (Ramachandra et al., 2017, Sharma & Jain, 2020). This increased demand for resources has led to a concerning rise in MSW generation, with estimates projecting a staggering increase to 165 million tonnes by 2031 and 436 million tonnes by 2050 (Chand Malav et al., 2020). This alarming trend underscores the urgent need for effective waste management strategies to mitigate environmental and public health risks. Municipal Solid waste is one of the main factor of Urban flood due to chocking of drainage (Ramachandra & Bharath, 2017) Despite an annual 5% increase in MSW generation, inadequate financial resources and technology continue to hinder proper waste management practices (Chand Malav et al., 2020). Swift action is crucial to address this escalating crisis and protect the well-being of urban communities and the environment. Further complicating MSW Management (MSWM) in urban India is the widespread neglect of waste segregation. Annually, in metropolitan cities, around 150 million tonnes of construction waste is generated, with only 10% being recycled, resulting in illegal dumping (Shubhi et al., 2023). Proper disposal is necessitated by the high urbanization rates in India, which leads to 530MT of C&DW annually(Souvick et al., 2023). In India, healthcare waste management is lacking, with hazardous waste being properly segregated in less than 50% of facilities (Shantanu et al., 2022). The lack of proper waste segregation results in a mixture of various waste types, including hazardous materials like single-use plastics and industrial/ hospital chemical waste (Joshi & Ahmed, 2016). This unsorted waste poses significant environmental and health risks, such as clogged drainage systems during monsoon seasons, leading to urban flooding and micro-plastic water pollution (Andersson & Stage, 2018). Further more, inadequate waste segregation

*M. Tech. Scholar, Ranbir and Chitra Gupta School of Infrastructure Design and Management, (RCGSIDM), IIT Kharagpur.
** Research Scholar, Department of Civil Engineering, IIT Kharagpur
*** Associate Professor, (RCGSIDM), IIT Kharagpur
,**** Professor, Department of Civil Engineering, IIT Kharagpur

hinders recycling efforts, despite India's growing recycling mark (Das et al., 2019). Additionally, neglecting segregation at landfill sites attracts animals and pests, posing health hazards to frontline workers and waste pickers (De Bercegol & Gowda, 2019). Municipalities primarily focus on waste collection, neglecting advanced treatment options, further exacerbating the MSWM issue (Iyamu et al., 2022). Essentially, the absence of source segregation hinders every aspect of waste management, highlighting the critical need for comprehensive segregation practices (Ramachandra et al., 2018)) However, effective waste management strategies not only rely on infrastructure and regulations but also on understanding how individuals perceive and engage with waste management rules. Governmental efforts to enforce waste management regulations may encounter challenges if not accompanied by an understanding of public awareness and perception regarding these rules. Research conducted in the National Capital Delhi reveals that a significant portion of respondents are unaware of the Municipal Solid Waste Rule 2016 (Wadehra & Mishra, 2018). These findings underscore the importance of assessing public perception and knowledge levels before implementing waste management regulations.

Theory of Planned Behaviour (TPB) offers a well-established framework for comprehending and predicting human behaviour (Ajzen, 1991). This theory posits that individual Behavioural intentions, shaped by Personal Attitude (PA), Subjective Norms (SN), and Perceived Behavioural Control (PBC), exert a significant influence on actual Behaviour (Ajzen, 1991). Applied to waste segregation practices, TPB suggests that an individual's intention to engage in dedicated waste separation and recycling is influenced by the perceived benefits or drawbacks of these actions (AT), social pressures from their social circles (SN), and their perceived ability to perform these actions (PBC) (Kumar & Agrawal, 2020).

Research has demonstrated that positive attitudes towards waste segregation, supportive social norms, and a sense of control over waste management processes can all positively influence household participation in waste separation activities (Razali et al., 2020). Additionally, TPB emphasizes the importance of addressing key drivers and barriers to recycling Behaviours through targeted interventions (Ajzen, 1991). By fostering favourable attitudes, encouraging social support, and enhancing individuals' perceived control over waste management actions, governments and policy makers can effectively promote and sustain waste segregation practices within communities (Kumar & Agrawal, 2020). India faces a critical challenge in waste management, particularly regarding waste segregation, the foundation for successful waste handling. This study seeks to understand why individuals fail to practice source segregation and how their PA, social surrounding, and knowledge influence their behaviour. While numerous studies in India examine waste management technologies, few explore the psychological factors impacting its practice. This research aims to bridge this gap by studying the factors related to human psychology that influence Waste Segregation Intentions (WSI) and examine how residents perceive challenges in waste management.

METHODOLOGY

Study Area

The study focused on households and their involvement in waste generation and disposal. It was conducted in Jamshedpur, first industrial city of India, located in the state of Jharkhand. The city is managed by three entities: a private entity, a municipal corporation, and a notified area committee. The survey targeted households within the service area of Jamshedpur Utility Services Company Limited (JUSCO), the private entity managing that specific area (Service Area), and the Jamshedpur Notified Area Committee (JNAC) area, managed by the local government (Non-Service Area). An equal number of surveys questionnaire sets (300) were distributed in both areas for data collection. The survey period spanned from December 20th to December 30th, 2023.

QUESTIONNAIRE DESIGN

The questionnaire was designed according to the

previous references and expert opinions. Designed to assess five key areas, the questionnaire used targeted questions to gauge respondent's personal opinions on waste segregation (PA), their perceived ability to control their behaviour (PBC), the influence of social pressures (SN), their likelihood to engage in waste segregation (WSI), and their willingness to accept financial penalties for non-compliance (willingness to pay penalty fee). A Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) facilitated data collection and analysis across all sections. This design examined not only respondents' attitudes towards waste segregation but also the impact of social norms on their intentions and their willingness to face consequences for non-compliance.

DATA COLLECTION

Data collection was conducted through in-person surveys. Survey teams conducted door-to-door visits, leaving questionnaires with unavailable respondents for later collection. A total of 600 surveys were distributed equally between teams assigned to the service area and non-service area. The survey period spanned 10 days. Following (Hair et al., 2012), an adequate response rate should be at least five times the number of questionnaire items. This study utilized a questionnaire with 17 items and received 537 valid responses out of 600 distributed (300 from the service area and 237 from the non-service area), resulting in an effective response rate of 89.5%. This comfortably exceeded the recommended threshold, ensuring the representativeness of the collected data.

DATA ANALYSIS

SPSS 29 is used to carry out the data analysis. For reliability of the questionnaire Cronbach's alpha test conducted and for sample adequacy KMO-Bartlett's test conducted using SPSS software. The study employed a scale validated in social and psychological research to measure the designated construct. This validation was established by Cronbach's alpha and composite reliability exceeding 0.70, aligning with established standards (Liao et al., 2018). The Cronbach's alpha value of 0.933 was calculated using SPSS, confirming that the questionnaire item demonstrates excellent reliability. Additionally, the sample adequacy check using a KMO value of 0.923 indicates that the sample is deemed adequate for the study.

RESULTS

Demographic Analysis

The socio-economic characteristics of the 537 respondents were divided into two parts: those from the service area and those from the non-service area. The demographic results in Fig. 1 depicts that in the service area, 67% respondents were male, while 33% were female. In the non-service area, 53% respondents were male, and 47% were female. This data suggests that there were more male respondents in the service area compared to the non-service area. Regarding education, approximately 39% of respondents in the service area had qualifications less than high school or up to high school, while this percentage was higher in the non-service area, with approximately 48% of respondents having qualifications less than high school or up to high school. A similar trend was observed in income levels, where around 35% of respondents in the non-service area had incomes in the range of 10,000-20,000 INR, while around 52% of respondents in the service area were in the range of 30,000-50,000 INR.

In the service area, most respondents worked at Tata Group companies, while in the non-service area, most people worked in the unorganized sector. Additionally, around 57% of respondents in the service area had full-time employment, while only around 30% of respondents in the non-service area had full-time jobs. In the non-service area, most of the female respondents were homemakers. When considering age groups, 29% of respondents from both areas belonged to the 35-44 age group. However, in the service area, this age group represented the majority, while in the non-service area, the most common age group was 25-34, with most of these respondents working in daily wage services.

QUESTIONNAIRE RESULT

Personal Attitude & Waste Segregation

The analysis comparing attitudes towards waste segregation in service and non-service areas reveals intriguing insights which are depicted in Fig. 2. In service areas where JUSCO offers waste

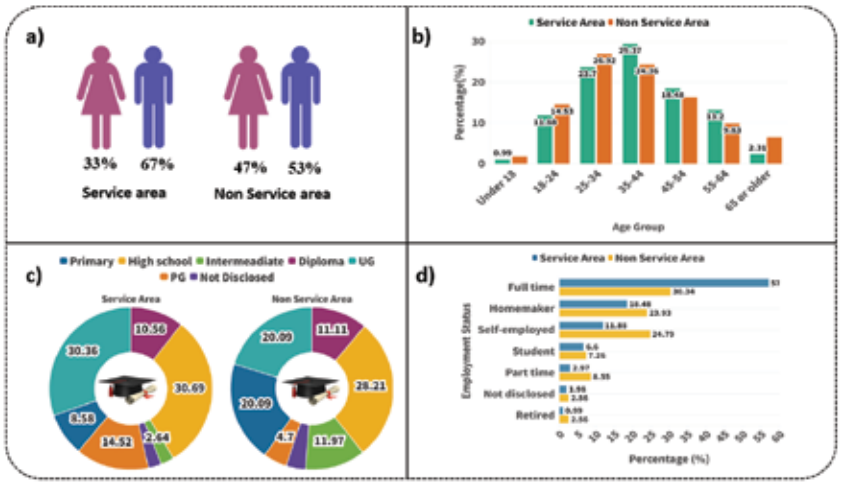

Fig. 1: Demographics of the study area a) Male-female proportion of the participants in the survey (b) Age distribution (c) Educational status d) Employment status of the participants

management services, there is a slightly lower inclination towards waste segregation (95%) compared to non-service areas (97%). However, in non-service areas, a higher percentage (94%) feel personally accountable for waste disposal compared to service areas (90%). Moreover, a larger proportion in non-service areas (94%) perceives over-generation of waste as a significant problem in landfills compared to service areas (95%). Similarly, more respondents in non-service areas (96%) perceive waste as a threat to health compared to service areas. Despite these differences, both areas display strong support for waste segregation at the source, with 95% in non-service areas and 93% in service areas acknowledging its potential to reduce landfill waste. Overall, individuals in both areas exhibit positive attitudes towards waste segregation, reflecting a sense of responsibility for addressing waste-related issues. Interestingly, the presence of formal waste management services in service areas does not significantly alter attitudes towards waste segregation, emphasizing the influence of individual perceptions and values over external factors.

Subjective Norms

Within the TPB framework, SN represent social pressures impacting individuals' waste management choices. Studies by, Liu et al. (2017), Pakpour et al. (2014) and Srun & Kurisu (2019), demonstrated significant positive effects of these norms on waste classification intentions (WCI). Park & Ha, (2014) observed increased resident motivation for waste segregation and recycling upon witnessing similar practices within their social circles. In non-serviced areas, 89% of respondents indicated a willingness to segregate waste if their neighbours did (Fig. 2). Despite residents' intentions, a gap exists between planned and actual waste segregation behaviour. Studies suggest that external factors like readily available infrastructure and supportive government policies can help bridge this gap. Research by Wang et al. (2018) confirms the positive influence of accessible infrastructure on waste classification, while Ma et al. (2020) found infrastructure to have the strongest direct impact in a study conducted in China's Shanxi Province. Residents in non-serviced areas demonstrated higher willingness to participate: 92% agreed to follow local regulations, a similar proportion supported government information campaigns, and 90% expressed interest in monetary incentives for segregation. Serviced areas reflected slightly lower enthusiasm, with 89% agreeing to regulations and information campaigns,

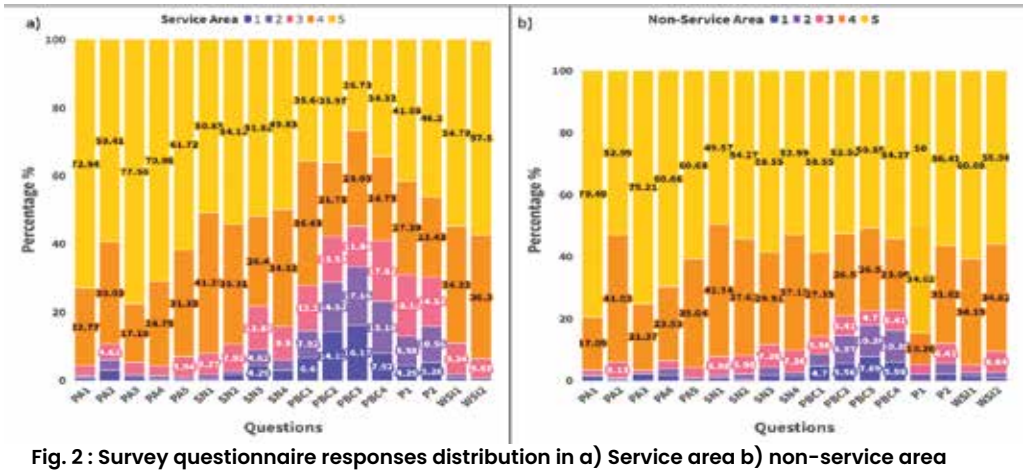

Fig. 2 : Survey questionnaire responses distribution in a) Service area b) non-service area

and 84% open to monetary incentives. These findings highlight the potential of external factors to address the intention-behaviour gap and promote wider adoption of waste segregation practices.

Perceived Behaviour Control

PBC within the TPB framework focuses on factors like time, energy, space, and perceived difficulty influencing WCI. It reflects an individual's belief in their ability to overcome barriers and perform the desired behaviour. In non-serviced areas, inadequate facilities, inconvenient drop-off sites (78% reported difficulty with locations over 100 metersaway),andalackofaccessibleinfrastructure (22% difference compared to serviced areas) significantly hinder waste segregation (Fig. 2). Additionally, 77% of respondents in these areas struggle with uncertainty about proper sorting and disposal, finding the criteria for different waste types complex. While serviced areas benefit from government awareness campaigns, leading to lower percentages (54% unsure about sorting, 57% finding criteria complex), knowledge gaps and infrastructure limitations remain challenges.

Penalty or Willingness to pay

Penalties are understood as economic instruments in the form of monetary fines imposed on individuals who fail to segregate recyclable materials at source. In non-serviced areas, a substantial majority of respondents (84%) believed a minimal nominal charge could improve waste segregation practices, and an even higher number (87%) supported fines for non-compliance (Fig.2). Serviced areas showed similar, albeit slightly lower, agreement with 68% and 70% of respondents endorsing minimal penalties and fines, respectively, as potential drivers of improved waste segregation behaviour.

Waste segregation Intention

Drawing upon the established theoretical framework of the TPB, encompassing Attitude, PBC, and SN, study explored waste segregation practices and intentions. In non-serviced areas, a remarkable 94% of respondents indicated an intention to participate in future waste segregation efforts, with 90% expressing willingness to engage if adequate facilities were provided by government or local authorities (Fig.2). Serviced areas demonstrated similar positive intentions, with 87% of respondents indicating interest in waste segregation and 93% agreeing to participate if proper infrastructure was available. These findings suggest a strong potential for promoting widespread waste segregation practices through targeted interventions addressing the key factors identified by the TPB framework.

DISCUSSION

According to the above analysis, significant positive impacts on WSI are observed due to PA, PBC, and SN. In both Service and Non-service areas, residents demonstrate an intention to segregate waste, yet face difficulties due to inadequate waste infrastructure. In Non-service areas, a lack of waste classification knowledge is prevalent among residents, while in Service areas, basic waste-related infrastructure and knowledge are provided by the service provider company, aiding residents in waste sorting. This underscores the strong explanatory ability of the TPB concerning residents' WSI. Neighbours influence residents' Behaviour in both areas, while Government Authorities' publicity aids in educating residents on waste sorting methods. Society plays a definitive role in waste segregation behaviour, past studies presenting varying views on the correlation between SN and WSI (Liu et al., 2017). Despite this, residents in both areas demonstrate a keen interest in waste segregation and exhibit a positive attitude towards penalties. They are willing to incur fines for non-compliance, believing that penalty charges will enhance waste segregation practices. Knowledge of waste classification is deemed crucial for promoting waste segregation, as demonstrated by research indicating that increased knowledge leads to higher participation. Moreover, residents perceive waste as a significant environmental and health concern, viewing segregation as a means to reduce health impacts. Incentive measures, such as discounts on utility bills, are seen as effective in promoting waste segregation practices, as they offer tangible benefits directly tied to segregation efforts.

CONCLUSION

Based on the TPB, the study reveals that the key factors affecting residents' WSI were identified. It was found that Jamshedpur residents' WSI is high, but its conversion into actual behaviour is low.

The main factors identified were PA, PBC, and SN. It was observed that residents have intention and a positive attitude towards waste segregation. However, due to the lack of satisfactory waste-related infrastructure and the complexity of waste classification knowledge, hurdles are created, especially for residents in non-service areas. The resident's perception is influenced by government publicity and policies related to WSI. With publicity about how waste should be classified, residents learn about the segregation process. Further more, the majority of residents of Jamshedpur, both from service and non-service areas, express willingness to pay fines for not segregating waste, which could be a major policy to lead people towards sustainable waste segregation processes. Based on the research conclusions, the following suggestions were put forward for a sustainable waste segregation process in Jamshedpur.

Waste Classification & Environmental Knowledge

Strengthening of publicity regarding the waste classification process, the benefits derived from it, and fundamental awareness regarding the generation of various types of pollution by waste, as well as how these pollutants impact residents' lives, is deemed necessary. Periodic conduct of awareness campaigns, seminars, street plays, etc., related to environmental challenges in schools and housing societies is advocated to ensure that knowledge is acquired, and awareness is raised among the populace.

Improve Waste Classification Infrastructure

The provision of adequate facilities and waste-related infrastructure for the practice of waste segregation should be ensured by the government and local authorities. The availability of multiple waste classification bins within proximity to societies, ideally within a distance of 100 meters, and the conducting of daily waste collection three times a day, with the availability of community bins equipped with classification boxes, should be guaranteed by governments and local authorities to facilitate waste disposal for residents.

Incentive Measures

The adoption of Waste segregation Behaviour is acknowledged as a long-term endeavour, necessitating consistent measures and incentives to ensure continuity. Incentive measures, which need not necessarily involve direct cash benefits but can be linked to discounts on monthly electricity bills, water bills, or house tax bills, are seen as encouraging factors for sustaining such behaviour. Additionally, the establishment of policies and formal sectors to support initiatives offering direct cash incentives for the replacement of e-waste, plastic waste such as bottles, and metal scraps by numerous companies is advocated.

Penalty for Non-Compliance

Implementing penalties for failure to practice waste segregation at the source and heavily penalizing actions such as dumping waste on road sides and littering could effectively discourage such behaviours among the populace.

Supervision and centralised system

A well-established centralized system for waste management is deemed essential within the city. Adequate training and education regarding waste management should be ensured to be offered to employees working within the city's waste management authority, and each collection vehicle should be equipped with a supervising professional on board to oversee both the collection workers and households, ensuring compliance with the established rules.

The foundation step for a sustainable and efficient waste management cycle is waste segregation. Waste management is not solely the responsibility of the government or local authorities; it is dependent on both government and public participation. Without public participation, it will never be successful. Prime examples such as Indore city, where coordination between the local authority and residents led to Indore becoming India's cleanest city, demonstrate that Jamshedpur or any other Indian city can achieve the same.

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CLIMATE CHANGE AND RESILILIENCE

USHA BATRA*

Abstract

Climate change is a threat to human well-being and planetary health. There is a rapidly closing window of opportunity to secure a live able and sustainable future for all. Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals.

Human-caused climate change is already affecting many weather and climate extremes in every region across the globe which has led to widespread adverse impacts and related losses and damages to nature and people. Climate resilient development integrates adaptation and mitigation to advance sustainable development for all, and is enabled by increased international cooperation including improved access to adequate financial resources, particularly for vulnerable regions, sectors and groups, and inclusive governance and coordinated policies.

Future climate change is projected to increase the severity of impacts across natural and human systems. Limiting warming to 1.5 and 2°C involves rapid, deep and in most cases immediate greenhouse gas emission reductions. Some future changes are unavoidable and/or irreversible but can be limited by deep, rapid, and sustained global greenhouse gas emissions reduction. The likelihood of irreversible changes increases with higher global warming levels. Deep, rapid, and sustained mitigation and accelerated implementation of adaptation actions in this decade would reduce projected losses and damages for humans and ecosystems and deliver many co-benefits, especially for air quality and health. Delayed mitigation and adaptation action would lock in high-emissions infrastructure, raise risks of stranded assets and cost-escalation, reduce feasibility, and increase losses and damages.

India has made significant progress in renewable energy capacity installation, domestic production of solar technologies, and ramping up the production of green hydrogen. Finance, technology and international cooperation are critical enablers for accelerated climate action. Enhancing technology innovation systems is key to accelerate the widespread adoption of technologies and practices.

INTRODUCTION

The entire globe is going through a transition, a series of challenges, propelled by the unprecedented crisis, one after the other, continuous disaster risks. Reversing climate change requires our unwavering attention and commitment.Climate change refers to the long-term alteration of temperature and typical weather patterns in a place. These changes are primarily caused by human activities, such as burning fossil fuels, deforestation, and industrial processes, which release greenhouse gases into the atmosphere and trap heat. Impacts include rising temperatures, sea levels, and extreme weather events.

Climate resilience refers to the ability of a community, ecosystem or system to anticipate, prepare for, and adapt to the impacts of climate change. It involves building the capacity to withstand and recover from climate-related events like droughts, floods, heatwaves, and sea level rise. Building resilience requires a multi-pronged approach, including:

- **Mitigation:** Reducing greenhouse gas emissions to slow down the pace of climate change.
- **Adaptation:** Preparing for and adjusting to the impacts of climate change that are already happening.
- **Research and development:** Investing in technologies and strategies to address climate change challenges.

* *Former SDG, CPWD*

- **Community engagement:** Empowering individuals and communities to take action and build their own resilience.

INDIA'S ACHIEVEMENTS AND CHALLENGES

India faces both significant challenges and achievements in its fight against climate change. Here's an overview:

Achievements

- **Renewable energy:** India is a global leader in renewable energy expansion, boasting the fifth-highest installed solar power capacity and ranking fourth in wind power. The government has ambitious targets for further scaling up renewables, aiming for 50% of energy capacity from non-fossil fuels by 2030.
- **Energy efficiency:** India has implemented various initiatives to improve energy efficiency across sectors, such as LED bulb distribution, building energy codes, and industrial efficiency programs. These efforts have led to significant reductions in energy consumption compared to business-as-usual scenarios.

Fig. 1 : India's achievements in fighting Climate Change

- **Forest conservation:** India's forest cover has increased by nearly 10% since 2013, thanks to initiatives like afforestation, forest fire prevention, and community-based forest management. This has enhanced carbon sequestration and ecosystem resilience.
- **Climate-smart agriculture:** The government has launched various programs promoting drought-resistant crop varieties, water-efficient irrigation technologies, and sustainable agricultural practices. These initiatives help farmers adapt to changing weather patterns and maintain food security.
- **International collaboration:** India actively participates in global climate change initiatives like the Paris Agreement and champions South-South cooperation on climate action. These helps share best practices and mobilize resources for developing countries.

Challenges:

- **High dependence on fossil fuels:** Despite renewable energy growth, coal remains the dominant energy source in India, accounting for over 50% of power generation. Phasing out coal and transitioning to clean energy sources remains a significant challenge.
- **Vulnerability to climate impacts:** India is particularly vulnerable to climate change impacts like heat waves, droughts, floods, and rising sea levels. These events threaten lives, livelihoods, and infrastructure, impacting millions of people.
- **Limited financial resources:** Implementing ambitious climate action plans requires significant financial resources. While India has made progress in mobilizing domestic and international funds, the gap between needs and resources remains substantial.
- **Equity and access:** Ensuring equitable access to clean energy, climate-resilient technologies, and adaptation resources is crucial, particularly for vulnerable communities and marginalized groups. Addressing social and economic inequalities is essential for effective climate action.
- **Capacity building:** Building the necessary capacity at all levels, from government institutions to local communities, is crucial for effective implementation of climate action plans. This includes technical expertise, financial management skills, and community engagement strategies.

GLOBAL WARMING - 1.5°C – 2.0°C

In recent years, the world has been grappling with the severe consequences of climate change, ranging from floods, droughts and melting of glaciers to rising temperatures and sea levels. These threats are not only affecting the

environment but also endangering the health and well being of humans and other living beings. The impact of these environmental hazards has been felt globally, including in India. Many countries across the world, including India are taking various sustainable initiatives to tackle climate change. As per HT dtd 10.01.24, year 2023 was 1.48°C warmer than 1850-1900 pre-industrial average i.e. barely below 1.5°C limit, the world is hoping to stay, to avoid the most severe effects of climate crisis, stated by Dy Director of the Copernicus Climate Change service (C3S). It is also likely that a 12 month period ending Jan/Feb 2024 will exceed above 1.5°C pre-industrial level. The weather extremes are evidence of how far humanity has reached from the climate in which it developed and how poorly the world is prepared for the growing risks of Climate Change. Only way forward is to reduce emissions and move to renewable energy sources. Developed Nations, who emit more should make stronger commitments to reduce GHG emissions.

Climate-related risks for natural and human systems, health, livelihoods, food security, water supply, human security, economic growth biodiversity and ecosystems, are higher for global warming of 1.5°C than at present, but lower than at 2°C These risks depend on the magnitude and rateof warming, geographic location, levels of development and vulnerability, and on the choices andimplementation of adaptation and mitigation options.

Limiting global warming to 1.5°C compared to 2°C is projected to reduce increases in ocean temperature as well as associated increases in ocean acidity and decreases in ocean oxygen levels, reduce risks to marine biodiversity, fisheries, and ecosystems, and their functions and services to humans,Hence adaptation needs will be lower for global warming of 1.5°C compared to 2°C butit would require rapidand far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems. These systems transitions are unprecedentedin terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors - a wide portfolio of mitigation options and a significant up scaling of investments in those options.Use of carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ over the 21st century which would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak , which is subject to multiple feasibility and sustainability constraints

Fig. 2: Climate Change Impacts

IMPACT OF CLIMATE CHANGE

The impact of climate change is felt in different ways in different regions of the world. In India, the impact felt is quite significant due to its large population, extensive coastline, and dependence on agriculture. The impact of climate change is felt globally but most acutely in developing countries, as they are less able to cope with the consequences of climate change and in several developed countries around the world it is leading to rising sea levels, melting of glaciers, ocean acidification, and loss of biodiversity. These impacts are causing environmental, social, and economic damage.

India's efforts towards climate change and environmental protection: India is the 7th most affected nation due to climate change as per Global Climate Risk Index 2021. Considering this, the Indian government has taken several measures to address climate change and protect the environment. India has set ambitious targets for reducing greenhouse gas emissions, increasing the share of renewable energy, and improving energy efficiency. India is also investing in innovative technologies to combat climate change. It is a leader in the development of solar energy technology, which is a clean and renewable

source of energy. Further more, it is also investing in the development of wind energy, biofuels, and energy storage technology. These technologies have the potential to reduce greenhouse gas emissions and mitigate the impact of climate change.

The world's efforts towards climate change and environmental protection: The world is taking several measures to address climate change and protect the environment. The United Nations Framework Convention on Climate Change (UNFCCC) is the primary international treaty aimed at addressing climate change. The Paris Agreement, adopted in 2015, is a global agreement to limit global warming to well below 2°C above pre-industrial levels. Several countries are leading the way in implementing sustainable solutions to address climate change and protect the environment. Denmark is actively implementing sustainable solutions, with wind turbines and solar panels supplying over 50% of the country's electricity today. China is the largest producer of solar energy in the world with a staggering production of 392 GW power. China is closely followed by the United States of America, Japan, Germany & India. Costa Rica is a leader in renewable energy, with over 98% of its electricity generated from renewable sources.

GAP IN COMMITMENTS & ACHIEVEMENTS

As per IRENA's report, It requires to triple renewable power globally. Group of 20 (G20) alone would need to grow its renewable power capacity from less than 3 terawatts (TW) in 2022 to 9.4 TW by 2030, accounting for 80% of the global total, whereas commitments made in NDCs are less than half of what they need to be to align with the tripling renewables pledge, and those made in national energy plans and policies fall short by 30%.

This necessitates an urgent and significant escalation of commitments. Despite global commitments, current financial and technological support for (Least developed countries) LDCs remains alarmingly insufficient, necessitating a significant scale-up in international assistance to achieve objectives that include, but also go beyond, climate.

SIDS (Small Island Developing States) have set ambitious renewable energy targets driven by objectives beyond climate, but almost half of this is conditional on international financial assistance. This has to be accompanied with a binding and robust framework for actual delivery of financing.

INDIA'S COMMITMENT TO NET ZERO

India has committed to achieving net-zero emissions by 2070, which will require significant investment. India needs approximately INR 11 lakh crores to meet its climate goals. To finance this transition, a variety of sources including the public sector, private sector, and international climate finance will be needed, necessitating increased commitments from developed countries.

However, the opportunities for sustainable growth are immense. With collective actions from all stakeholder groups, India can achieve its path to net-zero. At COP26, India presented five essential commitments, known as "Panchamrit," outlining a step-plan for a greener India (Fig.3).

INDIA'S TRANSITION TO SUSTAINABLE ENERGY

Government of India (GoI) has come up with various Performance Linked Initiatives (PLI) and policies to expedite the energy transition:

Renewable energy: India is the third-largest producer of renewable energy in the world, with 42% installed capacity coming from non-fossil fuel sources. With more than 150 GW of renewable energy already installed, about 80% of India's power capacity additions are expected to come from renewables as it chases a 500 GW RE goal to be achieved by 2030 (Fig 4). Over three quarters of this growth is expected from solar and wind, and rest from nuclear, hydro and biomass. Such large-scale renewable power capacity addition will help India achieve its NDC target of 50% of Non-Fossil Energy by 2030, and go on to meaningfully increase RE share further through 2047.

Energy storage: Energy storage is the missing link in the faster and wider adoption of renewable energy in the country. Owing the increasing share of variable renewable energy that will require storage, India will emerge as the third largest country in terms of energy storage installation by 2040. Battery manufacturing in India has been restricted to assembling packs from imported cells so far, in a fragmented market with many

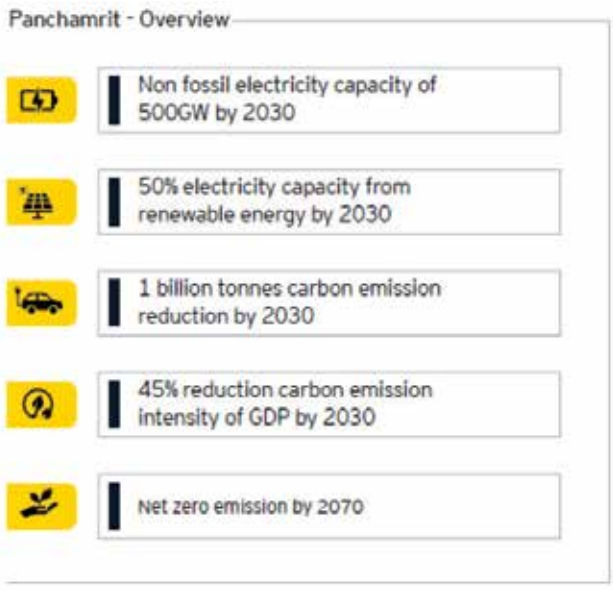

Fig. 3 : Panchamrit Overview

small players. With PLI for ACC batteries,end to end manufacturing of batteries at giga scale (>5GWh) is picking up, as large players have now started setting up facilities.

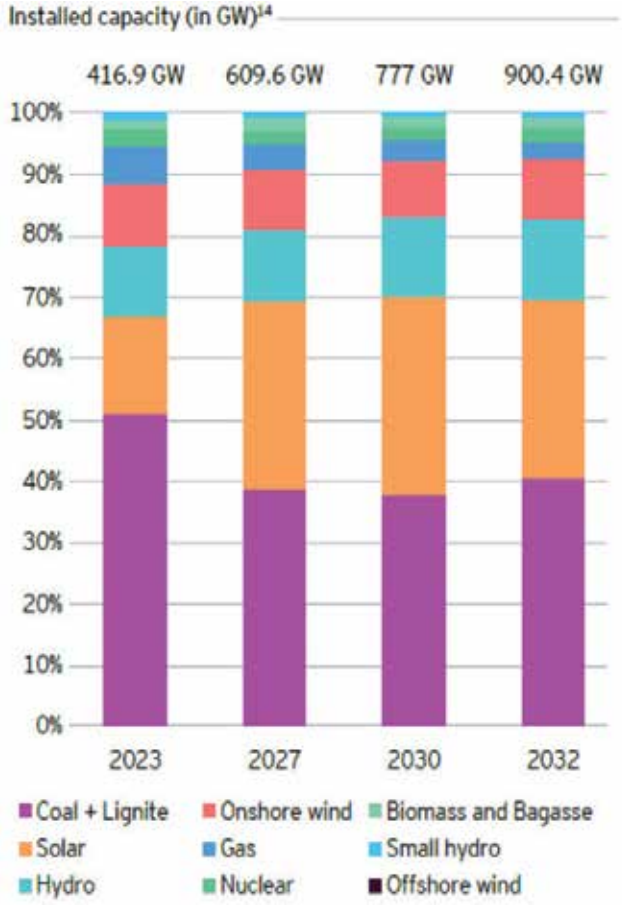

Fig. 4 : Installed Capacity in GW - YRS 23,27,30,32

Green hydrogen: Green hydrogen, produced by splitting water molecules in an electrolyser by using renewable energy or produced from biomass, is an emerging energy carrier with the potential to drive global decarbonization in hard-to-abate sectors. India already consumes about 6 million tons of hydrogen primarily for refining and fertilizers, which is currently produced from coal gasification or natural gas reforming and results in huge CO2 emissions. As a fuel, its applications vary across industrial heating, blending with natural gas for cooking or power generation, co-generation in coal-fired power plants, hydrogen combustion engines, fuel-cell-based electric vehicles or power backup, among others. Currently, green hydrogen production cost in India is around US$ 4-7/kg. For it to be competitive against alternatives across the applications mentioned above, green hydrogen production cost needs to go down to US$ 1-2/kg. India has a distinct advantage in driving this cost reduction through low-cost renewable energy, technology innovation, economies of scale, value chain integration, and policy and regulatory support.

Electric vehicles: Further, India has targets to achieve 30% penetration of electric vehicles in the overall vehicle sales by 2030. This will not only reduce harmful GHG emissions from Internal Combustion Engine (ICE) vehicles but also helps in minimizing the cost of oil imports.

INNOVATIONS FOR CLIMATE CHANGE AND RESILIENCE

The fight against climate change and building resilience requires innovation across various sectors. some exciting advancements happening around the world are :-

Energy and Emissions Reduction:

1. **Renewable energy:** Solar, wind, geothermal, and tidal power are rapidly becoming more affordable and efficient. Countries like China, Germany, and the US are leading the way in solar energy installations.
2. **Energy storage:** Technologies like batteries and pumped hydro are making renewable energy more reliable and grid-friendly. Tesla's Powerwall and Megaton batteries are changing the game

Fig. 5 : Renewable energy, Energy storage, Green Hydrogen and EVs

for residential and industrial energy storage.

3. **Carbon capture and storage (CCS):** Direct air capture technologies are emerging to remove carbon dioxide from the atmosphere, while geological storage options are being explored to safely store captured carbon underground.

4. **Green hydrogen:** Produced from renewable electricity, hydrogen can be used as a clean fuel for transportation and industry, reducing reliance on fossil fuels. Australia and Germany are investing heavily in green hydrogen projects.

Climate-Smart Agriculture and Food Security:

1. **Precision agriculture:** Using sensors, drones, and AI to optimize water and fertilizer use, reducing waste and increasing crop yields.

2. **Vertical farming:** Growing crops in controlled environments closer to consumers, reducing transportation emissions and land use. Singapore is a global leader in vertical farming.

3. **Drought-resistant crops:** Developing crop varieties that can withstand drier conditions, ensuring food security in vulnerable regions. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is at the forefront of this research.

Climate Adaptation & Resilience:

1. **Early warning systems:** Using AI and advanced weather forecasting to predict extreme weather events and help communities prepare. The World Meteorological Organization's Flash Flood Guidance System is an example.

2. **Nature-based solutions**: Restoring mangroves, wetlands, and forests can protect coastlines from flooding and storms, while also providing habitat for wildlife. The Philippines's "Green Wall" project is a successful example.

Fig. 6: Global Innovations for Climate Change and Resilience

3. **Climate-proof infrastructure:** Designing buildings and infrastructure to withstand rising sea levels, extreme weather, and other climate impacts. The Netherlands' Delta Works are a classic example of climate-proof infrastructure.

OTHER INNOVATIONS

- **Bioplastics and sustainable materials:** Developing alternatives to plastic made from renewable resources like plant-based materials, reducing reliance on fossil fuels and plastic pollution.
- **Clean water technologies:** Desalination advancements and wastewater treatment innovations are helping to address water scarcity in arid regions.
- **Blockchain for climate action:** Blockchain technology is being used to track carbon offsets and emissions, promoting transparency and accountability in climate action efforts.

These are just a few examples of the many innovations happening across the globe to address climate change and build resilience. As research and development continue, we can expect even more exciting advancements that will help us build a more sustainable and resilient future. It's important to remember that innovation alone is not enough. We need strong policies, international cooperation, and public engagement to ensure these technologies are implemented effectively and equitably.

CHALLENGES

While numerous innovations are emerging to combat climate change, several significant challenges stand in the way of achieving this target:

1. **Deep Emissions Cuts:**

- **Current pledges fall short:** Current pledges from countries under the Paris Agreement are not enough to limit warming to 1.5°C. A 2022 UNEP report found that even if all current pledges are met, temperatures would rise by 2.4°C by 2100.
- **Transformational shifts needed:** Deep cuts across all sectors, including energy, transportation, industry, and agriculture, are needed to achieve rapid decarbonization. This requires significant changes in infrastructure, technology, and behavior.

2. **Fossil Fuel Dependence:**

- **Fossil fuels dominate energy mix:** Fossil fuels like coal, oil, and gas still dominate the global energy mix, accounting for over 80% of primary energy consumption.
- **Phasing out fossil fuels is complex:** Transitioning away from fossil fuels is challenging due to their economic and political importance in many countries. Vested interests and concerns about energy security can create significant resistance to change.

3. **Technological Limitations:**

- **Renewable energy needs scaling up:** While renewable energy sources like solar and wind are growing rapidly, they still need significant scaling up to meet global energy demand.
- **Carbon capture and storage (CCS) is in its early stages:** CCS technologies are still in their early stages of development and face challenges of cost, scalability, and environmental concerns.

4. **Equity and Access:**

- **Unequal distribution of impacts:** Climate change impacts are not felt equally, with developing countries often bearing the brunt of the consequences despite contributing less to the problem.
- **Ensuring equitable access to solutions:** Developed countries have a responsibility to support developing countries in transitioning to clean energy and building resilience to climate impacts.

5. **Political and Social Challenges:**

- **Short-term vs. long-term priorities:** Climate action often requires long-term investments and sacrifices in the short term, which can be difficult for governments facing political pressure for immediate results.
- **Public awareness and engagement:** Public understanding and support for climate action are crucial for driving policy changes and individual behavioral shifts.

Despite these challenges, limiting warming to 1.5°C remains essential. The potential consequences of exceeding this target are severe, including more frequent and intense heatwaves, droughts, floods, and storms, rising sea levels, and mass extinctions.

CONCLUSION

- A growing coalition of countries, are pledging to get to net-zero emissions which requires our unwavering attention and commitment. It requires to triple renewable power globally.
- The weather extremes are evidence of how far humanity has reached from the climate in which it developed and how poorly the world is prepared for the growing risks of Climate Change. Only way forward is to reduce emissions and move to renewable energy sources. Developed Nations, who emit more

should make stronger commitments to reduce GHG emissions.

- The impact of climate change is felt globally but most acutely in developing countries, as they are less able to cope with the consequences of climate change.
- India has set ambitious targets for reducing greenhouse gas emissions, increasing the share of renewable energy, improving energy efficiency, innovative technologies to combat climate change.
- While numerous innovations are emerging to combat climate change, several significant challenges stand in the way of achieving this target which is not feasible without unprecedented level ofinternational cooperation in terms of finance and technology.

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IMPACT OF URBAN MORPHOLOGY ON THE MAIN MARKET STREET OF BILASPUR (H.P.)

DEVIBHUTI* AND BHANU M. MARWAHA**

Abstract

The swift growth of urban and peri-urban areas induces undesired variations in climate impacting building energy loads of heating and cooling. The built environment in an urban setting impacts the meso-climate, which depends on multiple urban planning factors. Urban street canyons affect the outdoor and indoor thermal comfort of the users mainly depending on their street geometry, orientation, aspect ratio, etc.

This study is an attempt to investigate the issues pertaining to user comfort in the Main market street of Bilaspur Town Himachal Pradesh. The survey conducted highlights the problems in outdoor thermal comfort amongst users influenced by the urban morphological characteristics of the street canyon. It also discusses the historical events and geographical constraints that led to the present scenario of this market street. Located in the city core, it is a part of the quotidian pedestrian commute alongside customers and sellers keeping the thorough fare busy throughout the day. The survey results bring out the user perception in reference to thermal comfort and suggest measures for mitigation of user thermal discomfort.

INTRODUCTION

The dispersed urban form provides a given thermal performance different from that of the compact urban form. Form to some extent modifies the micro-climate of the site and offers an improvement of ambient temperature and therefore increases human comfort. The decision on the city's residential orientation has an impact on human health, degree of comfort, and energy consumption. The degree of exposure to solar radiation is important in establishing the various land uses in a settlement and the house de sign details. However, a decision on orientation should be a synthesis of the reciprocal relations among solar radiation, ventilation, heat exchange, view and landscape, and relative humidity (Gideon S. Golany, 1995). The definition of thermal comfort is according to three different approaches: the psychological, the thermo physiological, and one based on the heat balance of the human body (Peter Hoppe, 2002). Urban morphology is a more precise term because it signals a specifically articulated approach to its study and a definite set of content. It is the study of built forms of cities, and it seeks to explain the layout and spatial composition of urban structures and open spaces, their material character and symbolic meaning, in light of the forces that have created, expanded, diversified, and transformed them (Conzen, n.d.). The study of urban morphology focuses on the built environment of cities, but it also aims to reveal the "genesis" or "engendering process" of this form (Karl Kropf & Sylvain Malfroy, n.d.). It follows, then, that urban morphology concerns the associations between buildings and other spaces across the whole territory of cities, or selected districts within them, rather than isolated buildings, and that these associations are the principal focus, across space and time. Urban morphology, which includes building volume, pervious and impervious materials, open and green areas, surface materials (ground and facades), direct sun exposure on the building façade, and other factors, affects the outdoor air temperature. The current study is an attempt to identify the issues related to the comfort level of human activities and major existing weather parameters in the urban environment. This has been accomplished by means of a user feedback survey. While the weather, urban morphology characteristics, and their interactions with street thermal comfort will be covered in a separate article, the findings of questionnaire surveys are examined in this one.

** M. Arch Scholar, National Institute of Technology, Hamirpur, Himachal Pradesh*

*** Professor, National Institute of Technology, Hamirpur, Himachal Pradesh*

MATERIALS AND METHODS

Bilaspur is a south western district of Himachal Pradesh, popularly known for its sports facilities in the state situated at 31°34′ latitude, and 76°68′ longitude. The average elevation of the town headquarters is 673 m from the main sea level. Gandhi Market (Lower Main Market) and Main Market are the locations of my research. Both markets are in the downtown area, separated by National Highway 154, and include mixed-land use (shop/residence). Fig. 1 illustrates the detailed location of the study area.

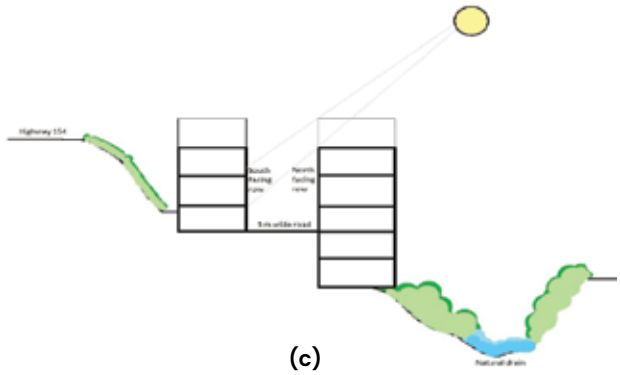
(a) (b) (c)

Fig. 1: Shaded areas are marked to signify the location. (a) District Bilaspur in Himachal Pradesh, (b) Tehsil Sadar in District Bilaspur, and (c) Study area of Market Street in Tehsil Sadar.

The district with an estimated population projected to be 4.17 lakh, indicating a 9.1% increase from its population in the 2011 census majorly has a rural population of 3.57 lakh and only 25,130 of its population resides in urban (Bilaspur Population, n.d.). The town is in a sloppy terrain where it lacks continuous airflow due to its morphology, where the Main market's elevation began at 600 m from one point to 584 m till its endpoint then exited the National Highway. Gandhi market terrain level began at 584 m, which dropped to 580 m and then rose to 590 m. Collectively, the level difference between the two ends of Main Market and Gandhi Market is 16 m and 10 m respectively. The floors on the street level are dedicated to shops and the floors above are to residences where most of the plots are five-story high, where two-story are below street level and three-story are above the street level. Bilaspur is in the Shivalik range also known as Outer Himalayas of Himalayan Mountain ranges having an elevation range from 600 m - 1500 m. It lies in the 'Monsoon-Influenced humid subtropical climate' (Cwa) of the Koppen-Gieger climate classification where the climate is Temperate, dry winter and hot summer. Here, the coldest month averages above 0°C, at least one month's average temperature is above 22°C, and at least four months averaging above 10 °C also where 70% or more of average annual precipitation is received in the warmest six months (Humid Subtropical Climate, n.d.). Fig. 2 illustrates the aerial view of the town and study area mentioned in the yellow dotted line. Other major urban nodes and urban districts are also mentioned a plan of the market, and a typical site section.Market Street is in the city core and is bordered by a main bus stop, a shopping mall, and a Government Degree College, creating a busy location for both vehicular and pedestrian movement. On all sides of the Market Street are residential districts, a bus stop, and a shopping mall at the intersection of both Main market and Gandhi market results in traffic congestion during peak hours. Being surrounded by multiple activity zones the street is a part of daily commute along with a shopping-cum-residential area. Narrow and deep streets have a lesser Sky View Factor (SVF) which provides a comforting environment for a composite climatic region for the summer whereas for harsh winters such a situation becomes a concerning issue w.r.t. human thermal comfort. Parts of the street have solar pockets solely for the reason of unoccupied opposite land.

(a)

(b)



(c)

Fig. 2 (a): Aerial View of Bilaspur town and Study area, (b) Plan of the study area, and (c) A typical section of the site

RECONNAISSANCE SURVEY

The purpose of a reconnaissance survey in the study area was to identify the problems that users regularly encountered with thermal comfort. Given the built environment scenario, it is now necessary to identify and describe the issues. The survey was conducted among 92 people regarding thermal-related issues, depicting the people's perception in terms of air temperature comfortability of the street. Pedestrian and seller surveys have been conducted regarding the temperature throughout the year to know the area of problem for validation of the study. The respondents provided information more vividly describing the thermal comfort conditions, and a simple random sampling technique was used where both males and females from all age groups were selected for the study. Most of the sellers are the residents of the market. It explains the comfortable season and duration of the year. Issues people are facing that are being impacted by the existing urban morphology of the street are shown in Fig. 3, people's perception of outdoor comfort in the study area described through pie charts. The questionnaire for the survey follows;

- Do you own the shop or have it on rent?
- What is your length of stay in the market?
- Number of sellers having direct access to open space out of all 196 shops?
- Do you feel comfortable in summer?
- Do you feel comfortable in winter?
- Number of direct diurnal hours in summers out of total diurnal hours on summer solstice?
- Number of direct diurnal hours in winters out of total diurnal hours on winter solstice.

These charts are the results of the answers provided by the respondents, clearly stating that no access to direct sunlight in most of the streets accompanied by residents and pedestrians causes comfortable conditions during summers whereas uncomfortable conditions during winters. Only 15% of the

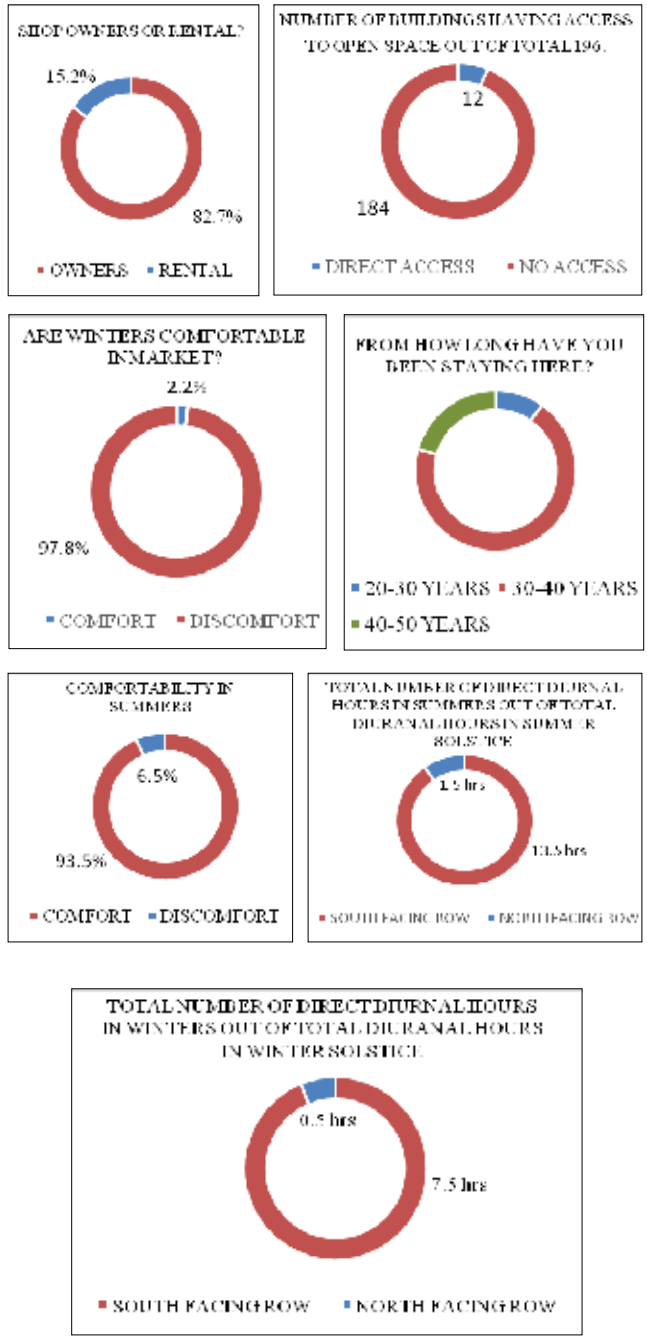


Fig. 3: Reconnaissance Survey

shops are rentals and nearly 82% of the total are owned by people who are living on the same street having the same residential space and workplace restricting them from always receiving any sunlight. Orientation of built form and aspect ratio of the study area play a crucial role in shaping the situation.

CONCLUSION

The street runs east-west and is surrounded by buildings that rise three to four stories above street level on both sides, creating a deep urban canyon. Due to the lack of solar penetration and prohibition of continuous airflow, noise, and lack of privacy, which cause negative influence on people's living environments. The survey concluded that winter was the most uncomfortable period or season of the year for most people whereas summer is mostly comfortable due to the north-facing row of buildings and roads being in the shade. In view of the geographical location and climatic zone to attain the thermal comfort in the winter, feasible interventions must be made in the street at the urban or building level. Such interventions have been discussed by Manni et al., (2023) and the passive solar strategies for planning and design at the neighbourhood and building levels. Incorporating façade reflectors can increase the heat in the urban canyon. Building form, morphological type (e.g., courtyard, high/mid/low-rise), and thermal mass alongside room depth and window-to-wall ratio determine the penetration of natural light into the building. Building massing (Van Esch et al., 2012) with east–west street direction and single-pitched roofs might be the preferred design options, for comfort during the cooler seasons.

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Indian Buildings Congress
Kama Koti Marg
Sector - VI, R.K. Puram, New Delhi - 110022