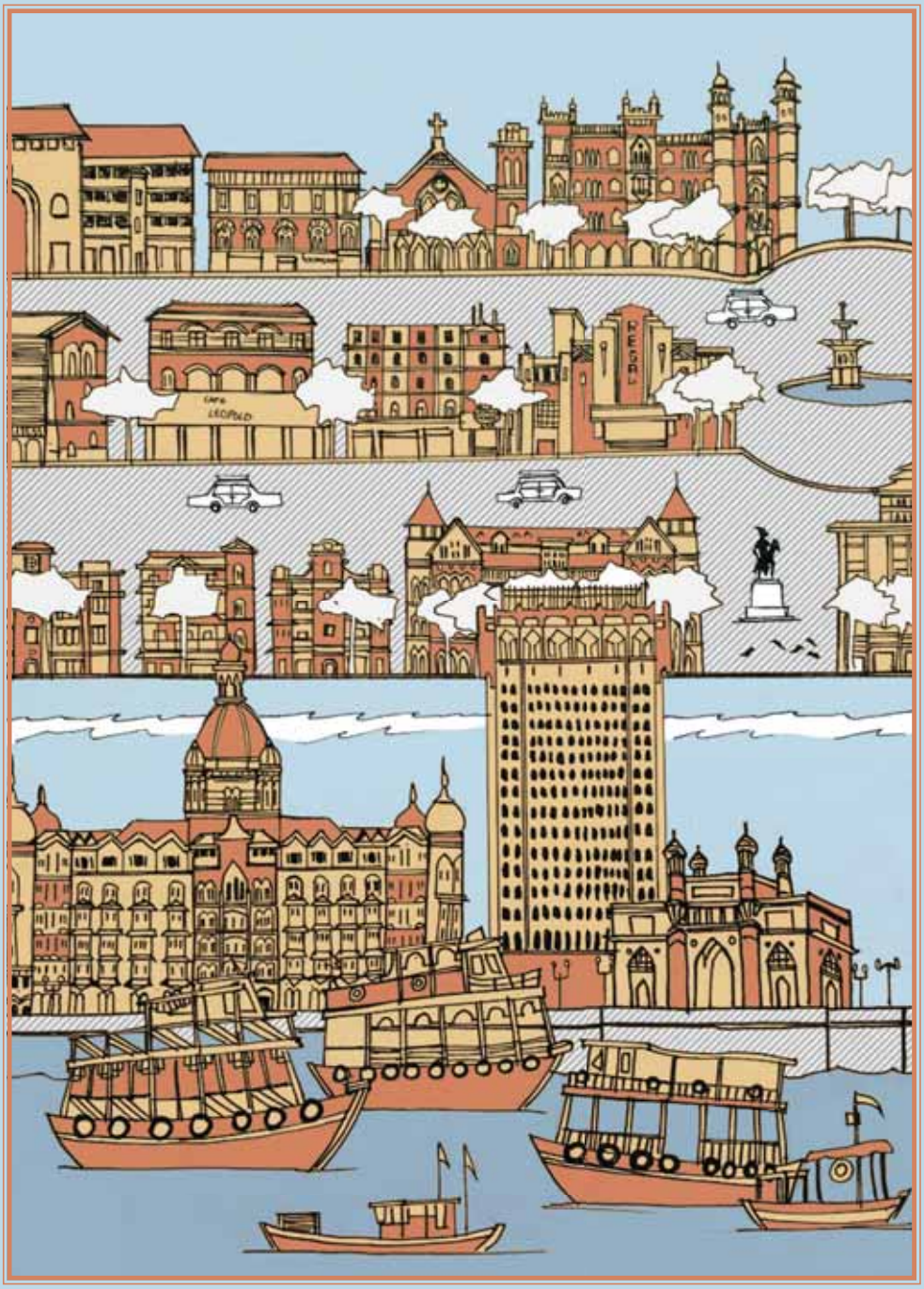
JOURNAL OF THE INDIAN INSTITUTE OF ARCHITECTS
PEER REVIEWED JOURNAL OF IIA ● ISSN-0019-4913
JUNE 2025 ● VOLUME 90 ISSUE 6 ● RS. 100



arcasia
Architects Regional Council Asia

THE 21ST ASIAN CONGRESS OF ARCHITECTS - INCHEON

2025.
9. 8. - 9. 12.
Incheon, KOREA

HOST
Korea Institute of Registered Architects
Incheon Metropolitan City

ORGANIZER
17 KIRA Chapters

SUPPORT
국가건축정책위원회
Ministry of Land, Infrastructure and Transport
Korea Heritage Service
Incheon Metropolitan Council
FIKA 한국건축예술인
CERTIFIED ARCHITECTS FINANCIAL COOPERATIVE
FCA The Federation of Construction Associations
KOREA TOURISM ORGANIZATION

Website: https://aca-21.kr
E-mail: aca21.arcasia@gmail.com

Jai Hind From Orbit: Shubhanshu's Stellar Tribute

CONTENTS

Dr. Abhijit Natu

Dr. Parag Narkhede

Dr. Abir Bandyopadhyay

Dr. Chandrashekhar

Dr. Rama Subrahmanian

Dr. Aarti Grover

BOARD OF REVIEWERS

Dr. Ajay Khare

Ar. Jit Kumar Gupta

Ar. Mukul Goyal

Prof. Harshad Bhatia

ADVISORS IIA PUBLICATION BOARD

Printed & Published/Editor by Ar Lalichan Zacharias on behalf of The Indian Institute of Architects.

Designed by **India Printing Works**
Printed by **Arihant Digiprint**
Shed No.1, Ground Floor, CTS No.15, 16, 20, 21 & 37, Italian Compound, Dindoshi Village, Ittbhatti, Goregaon East, Mumbai-400063

Published at The Indian Institute of Architects, Prospect Chambers Annexe, 5th Floor, Dr. D.N. Road, Fort, Mumbai-400001.

+91 22 22046972 / 22818491 / 22884805
iiapublication@gmail.com
www.indianinstituteofarchitects.com

Editor Ar. Lalichan Zacharias
Kakkamthottil, Jaya Nagar, Marudu P.O., Pachalam S.O., Maradu, Dist-Ernakulam, Kerala-682304.
R.N.I. No.9469/57
lalichanz@gmail.com

Advisors : **Ar. Mukul Goyal**

Printer's Email
arihantdigiprint.offset@gmail.com
krish.graph2021@gmail.com

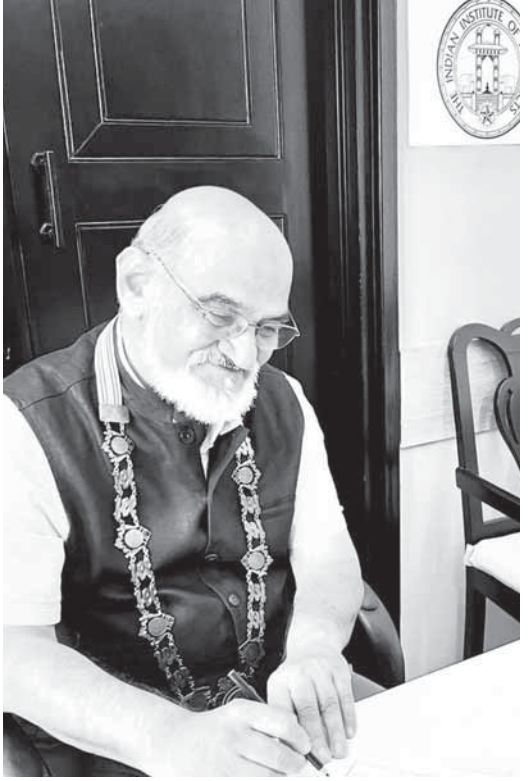
JIIA IS A REFEREED JOURNAL
ISSN 0019-4913

REGISTERED UNDER SOCIETIES REGISTRATION ACT XXI OF 1860.

JOURNAL OF THE INDIAN INSTITUTE OF ARCHITECTS
VOL. 90 - ISSUE 6 - JUNE 2025

www.indianinstituteofarchitects.com

PRESIDENT'S MESSAGE



Dear IIA Members,

Greetings!

It gives me great pleasure to inform you about the significant amendments proposed to the Indian Institute of Architects (IIA) Bye-Laws. These amendments are designed to align our organisational framework with contemporary professional standards and global best practices. We believe that these changes will enhance the overall functioning and governance of the Institute, improve transparency and efficiency, and strengthen our collective ability to serve the architectural community across the country. These amendments will be formally presented for discussion and approval during the upcoming Special General Body Meeting scheduled for 26th July 2025. I encourage all members to participate actively and contribute to shaping the future of our Institute.

However, it is with concern that I must also address a matter that threatens to undermine our collective efforts. There have been instances of misinformation being circulated by a few of our own members, leading to confusion and a negative atmosphere within the Institute. Such actions, while limited in origin, have a disproportionately large impact by delaying important decisions and obstructing the path of progress and development. It is crucial that we remain united, transparent, and focused on our common goals.

Apart from this, I am delighted to share two important achievements that mark a new milestone for IIA on the international platform. The IIA has successfully won the bid to host the prestigious UIA International Forum in 2027, as well as the ARCASIA Forum in 2026. These forums represent a significant recognition of India's growing presence and leadership in global architectural discourse. I am confident that with the continued dedication, coordination, and enthusiasm of the National Council and all our members, both events will be organised in an exceptional manner and will reflect the excellence and spirit of Indian architecture.

I truly believe that the proposed amendments and our recent international achievements are steps in the right direction and will go a long way in reinforcing the credibility and strength of the IIA.

Therefore, I sincerely appeal to all members to channel their energy into constructive contributions that support the growth and vision of the Institute. Let us work together to uphold the integrity and dignity of our profession. Your cooperation and commitment are vital to overcoming challenges and achieving greater success.

Yours Sincerely,

Ar. Vilas Avachat
President
The Indian Institute of Architects

IIA OFFICE BEARERS

Ar. Jitendra Mehta
Vice-President, IIA

Ar. Tushar Sogani
Jr. Vice President, IIA

Ar. Sudhir Pillai Balakrishna
Hon. Treasurer, IIA

Ar. Akshaya Kumar Beuria
Jt. Hon. Secretary, IIA

Ar. Ranee Vedamuthu
Jt. Hon. Secretary, IIA

Ar. Sandeep Bawdekar
Jt. Hon. Secretary, IIA

Ar. Chamarthi Rajendra Raju
Imm. Past President, IIA

EDITOR'S NOTE

Greetings to all IIA members from the JIIA Team.

June 2025 will be remembered as a pivotal month for India's built environment marked by monumental accomplishments, urgent awakenings, and renewed commitments to sustainability. From grand openings to sudden failures, our architectural narrative has never been more dramatic or instructive.

The inauguration of the final 76 km stretch of the Mumbai–Nagpur Expressway on 5 June, Samruddhi Maha Marg is nothing short of transformational. This 701 km spine rewrites regional connectivity, halving travel time and threading through hundreds of villages via highspeed, 150 km/h design parameters and India's longest road tunnel at Kasara Ghat. For architects and infrastructure planners, this signals a new era where mobility, landscape integration, and engineering go hand in hand to shape regional development.

Even more profound is the 6 June flagoff of the direct Jammu–Baramulla railway link—including the world's highest Chenab bridge and India's first cablestayed rail bridge—creating a seamless spiritual corridor for pilgrims. It's a testament to design ambition meeting engineering courage, reinforcing the principle that architecture in rugged terrains isn't just about aesthetics—it's about optimism, connectivity, and resilience.

Finally, the early arrival of the southwest monsoon in June highlighted the urgency of adaptive design. Our climatic timeline is shifting our buildings must too. From floodresilient infrastructure to passive cooling systems, monsoon design needs to be embedded in every typology, large or small.

This surge in infrastructure development is opening up diverse opportunities for our fraternity. We must be prepared to seize them effectively and efficiently to showcase our progress on the global stage. Our Asian community ARCASIA is addressing these infra and urban issues by holding its 21st Asian Congress of Architects (ACA21), which will be hosted by Korea Institute of Registered Architects (KIRA) from 8th to 12th September 2025. We urge members of IIA to participate wholeheartedly in this conference to put up Bharatiya perspective to ensure our presence in terms of the largest democracy of Asian countries. We shall discuss how technology like AI is going to help as our collaborator in delivering quality services to society. Such discussion platforms shall be encouraged and to be participated to exchange ideas and way forwards for better future.

We extend our deepest appreciation to all dedicated IIA members whose tireless efforts have built platforms for meaningful engagement and rich knowledge exchange. Your commitment is instrumental in advancing Indian architecture and enhancing its global profile.

We also wish to express sincere gratitude to the authors whose thoughtful contributions have been vital to this collective endeavour.

We encourage all IIA members to actively engage in these initiatives and contribute to demonstrating our collective leadership on the global architectural stage.

Stay united and stay ahead.

Jai Hind.

Prof. Vinit Mirkar
JIIA Editor

EDITORIAL TEAM


Ar. Vinit Mirkar


Dr. Shilpa Sharma


Ar. Shruti Verma


Ar. Neha Sarwate


Dr. Sampada Peshwe

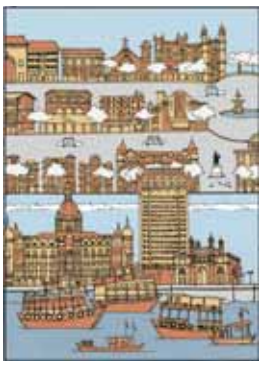

Ar Mrinalini Sane


Dr. Nabanita Saha


Dr. Pashmeena Ghom

COLABA AND APOLLO BUNDER

OUTLINES OF MUMBAI, WITHOUT ITS PEOPLE



Mumbai is the city of stark contrasts and combinations. It is one of those unique cities in the world, which has been graced by architectural works of varied eras and styles. In one part of the city, one may find a quaint Indo-Portuguese village, while in another, one may encounter a grand Victorian neo-gothic edifice, and in yet another part, one may come across an ancient Hindu temple tank nestled in a quiet locality. Strange, yet stunning: such is the identity of the 'City of Gold' and its intriguing farrago of architectural glamour.

In the southern part of the city, while exploring the city's grand and splendid Colonial architecture, tourists venture into the areas of Colaba and Apollo Bunder. These areas are a treasure trove of Colonial and a few Art Deco structures. In this illustration, the architectural heritage of these areas has been sketched, but with one condition in mind: without sketching any humans. There are taxis, there are ferries, there are crows, there are lampposts, there are trees, but there are no people. The whole idea behind this was to represent the identity and esteem of the city, without its main factor of identity: The people of Mumbai.

The illustration uses shades of orange to evoke the timeless expression and tactile essence that is shared by the colonial structures through the course of time. In the lower part of the illustration, the Apollo Bunder and the eastern waterfront of Colaba has been illustrated, with few of the most iconic architectural structures the city boasts of: the Gateway of India, the Taj Mahal Palace Hotel and the Taj Mahal Palace Tower. The busy Bombay harbour can also be seen, with its ferries and boats. This scene, this exact scene: ferries and boats sailing into the busy Bombay harbour, with the grand and majestic architectural icons in the backdrop, has come to represent the city of Mumbai as a whole. Above these, the illustration goes on to display several other iconic and beautiful buildings of Colaba, like the Regal Cinema, Majestic Aamdar Niwas, Metro House, Royal Bombay Yacht Club, Cusrow Baug, Dhanraj Mahal, Electric House, Cafe Leopold, et al. The illustration focuses on the structures along the Apollo Bunder waterfront, Colaba Causeway, and the Wellington Circle. Someone familiar with Mumbai's heritage and architecture would be quick to spot the Wellington fountain and the statue of Chhatrapati Shivaji Maharaj incorporated into the illustration, which form a major part of the identity of these regions.

Sanskar R. M. Khatri is a IV year Architecture student at the Rachana Sansad's Academy of Architecture, Mumbai, Maharashtra. He is doing an internship at Abha Narain Lambah Associates. He is passionate about exploring Mumbai's Architecture, from ancient to modern. He is specifically interested in the city's Colonial and Art Deco architectural heritage. He is an reader on topics pertaining to the history and origins of these buildings.

Email ID: skhatri21@aoamumbai.in

JIIA Call
for Papers, Articles, Projects

The Journal of the Indian Institute of Architects invites original and unpublished contributions from members **ONLY** (academicians, practitioners and students) under the following FIVE categories. Submission in each category is strictly only through the respective google forms.

In order to be accepted for publication, all material sent in these categories should have the following components:

1. MS Word document file with text only. Please do not format it in anyway. The numbered captions for all the images will also be in this document.
2. Folder with all images (minimum 300 dpi), numbered according to the captions given in your text file
3. Photograph of the author/s (minimum 300 dpi).
4. Author biodata – Maximum 50 words.
5. PDF (optional)– showing the intended layout. This pdf should include text and all images, with numbered captions.

Category 1 : Articles

google form link: https://forms.gle/7pDFva1HDH4hfUyj8

Essays, interviews, articles (1500- 2500 words), book reviews (600 and 750 words), travelogues, sketches and photo-essays in the areas of architecture, planning, urbanism, pedagogy, heritage, technology, ecology, theory and criticism, visual design, practice or any other relevant subject pertaining to the built environment. (Details of the format will be available on the JIIA website).

- For a design project, please include the 'Fact File' with the following details : Project Name, Location, Plot area, Total built up, Structural consultants, Project completion. Also please give the photo captions and credits. Please ensure that the image is referred to within the text. For eg, "As seen in Figure 1…". This is essential for the layout.
- For design projects, plans and sections of the project are desirable along with the photographs.
- Book reviews should be only of books by Indian authors. please include the "Fact File" with the following details: book title, author name, publisher, year of publication, ISBN, language the book is written in, genre (technical/ fiction/ etc.), no of pages, dimensions (in cm), type (Kindle/ paperback/ hardback), available at (amazon.in/ flipkart.com/ others).
- Please send a write-up of about 200-300 words along with sketches and photo-essays.

Category 2 : Student Work

google form link: https://forms.gle/hyhsCoK6QPe6qDJu8

Summaries of dissertations (2000-3000 words) at the level of B.Arch. & M.Arch., and theses at the Ph.D. level. The Guide for that work will be mentioned as the Co-author. (Format will be available on the JIIA website).

Category 3 : Contributions from Chapter Correspondents

google form link: https://forms.gle/Ru4JBLSHwaYEBTcg7

(a) *Chapter News:* This includes various interesting activities from the Centres of your Chapters (maxm. 500 words for the news from the *entire* Chapter).

(b) News of conferences by the academic institutes in your respective Chapters.

(c) *Obituaries :* Obituaries of IIA members should consist of the photograph of the departed soul, the dates of birth and death and a short 50-word note.

Category 4 : Research Papers

google form link: https://forms.gle/Z9YWQQMaw843N1eT6

Research papers (2000-5000 words) in the prescribed format. The research may be based on their ongoing or completed research. (Format is available on the JIIA website). All contributions in this category will be double blind peer-reviewed before being accepted for publication by academic experts of repute.

Category 5 : Cover Design

google form link: https://forms.gle/BSkuE5cApXdy7dX1A

Students from affiliated colleges are invited to design the cover page theme. This should be a graphic based on some aspect of Indian Knowledge Systems. The submission will include the graphic file (jpeg or corel draw); a theme note (with a title) of about 500 words explaining the concept of the graphic.

Please note that the image you send will be adjusted as per the layout requirements of the JIIA Cover.

Please note:

1. All submissions will be accepted only through google forms.
2. Submissions will **NOT** be accepted through email.
3. Any queries to be addressed to : jiiaeditorial@gmail.com.
4. When you correspond with us, please give your email id (that you regularly use) and your cell no. (preferably with WhatsApp).
5. It is compulsory to mention your IIA regn. No. Submissions will **NOT** be accepted from non-members.
6. The review process takes anywhere between 4-6 weeks. Since it may not be possible to respond to all authors who send in their work, we will definitely revert if and when your work is accepted.
7. JIIA does not charge any fees for publication of any professional or academic work.
8. It is understood that submission from an author is an original work, unpublished anywhere else, and that IIA and JIIA are in no way responsible for any matter or dispute arising out of the publication of the same.
9. All authors are requested to refer to further detailed information available on the JIIA website.

RESEARCH PAPER

This research paper was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, 29-31 August 2024, under Stream 2: The Significant Present.

Assessment of Land Use Land Cover Changes of Peri-Urban Areas of Hyderabad Using Remote Sensing and GIS

By Sridevi T, Dr. S. Kumar and Ar. B. Sai Akhila

Abstract

The examination of alterations in land use and land cover has emerged as a vital component in modern approaches to natural resource management and the observation of environmental changes. The proliferation of urban environments has resulted in considerable reductions of agricultural land, grasslands, unutilized terrain and aquatic ecosystems. Evaluating urban expansion and analyzing land use and land cover (LULC) modifications is essential for promoting sustainable urban development. Engaging in research within these domains is critically important to ensure that cities grow responsibly and sustainably. Hyderabad, an increasingly prominent urban hub, exerts a significant impact on its adjacent areas, making it an exemplary site for such investigations.

This study assessed the changes in Land Use Land Cover (LULC) over a five-year duration (2017 to 2022), utilizing remote sensing and Geographic Information System (GIS) methodologies to discern transformations occurring in the peri-urban sectors of the Hyderabad Metropolitan Region. The research area was classified into five distinct LULC categories: constructed environments, water bodies, rangelands, agricultural zones and bare ground. The maximum likelihood method was applied to categorize Esri-Sentinel-2 imagery from five years through the supervised image classification technique facilitated by GIS software. The precision of the classified images was evaluated via an accuracy assessment procedure. The key outcomes of this research revealed substantial changes within the peri-urban landscape of the Hyderabad Metropolitan Region over the five years, particularly highlighting the conversion of arable lands into developed spaces designated for infrastructure and residential initiatives.

Keywords: Land Use Land cover, Remote sensing, Accuracy Assessment, Transition Matrix

1. Introduction

Metropolitan areas have significantly influenced human civilization, driving progress, innovation and art. Urbanization has increased over time, reshaping the global economy and social structures (Sun et al., 2013; Meng et al., 2022), leading to new lifestyles and values. While urban growth offers benefits, it also presents challenges like traffic congestion, environmental issues and loss of green spaces (Mohan et al., 2011; Zhong et al., 2022). This rapid expansion affects natural resources such as water, land and energy. From 2000 to 2030, the global urban population is projected to rise by 72%, with cities of 100,000+ residents expected to grow by 175% (Angel et al., 2005). Despite occupying a small portion of

Earth's land, rapid urbanization profoundly affects environmental conditions and social landscapes (Berling-Wolf & Wu, 2004; European Environment Agency (EEA & FOEN, 2016).

The occurrence of unchecked urban expansion has been recorded globally, raising apprehensions regarding its impact on adjacent peri-urban areas (PUAs) (Goswami, 2018; Jiang et. al, 2013; Tabuchi, 2013). Research indicates that the expansion and advancement of a major metropolis, along with its relationship with the PUA, are chiefly influenced by three principal factors: economic progression, the pace of trade growth and the political will of the government to foster urban development (Jiang et. al, 2013). Generally, urbanization is associated with a reduction or transformation in the use of cultivable land (Jiang et. al, 2013; Dadras et. al, 2014; Hu et. al, 2018). As a result, assessments of changes occurring within the Peri-Urban Area (PUA) are primarily carried out through analyses focused on alterations in land use and land cover (LULC) (Lutzenberger et. al 2014).

Hyderabad, situated in the state of Telangana, is recognized as the fourth most densely populated metropolitan area in India and is undergoing significant expansion within its adjacent territories. In this regard, the Hyderabad Metropolitan Development Authority (HMDA) released a Master Plan in 2013. This Master Plan outlines land use zoning that encompasses various classifications alongside peri-urban areas, incorporating 29 administrative divisions (mandals) into the previous master plan. Among these 29 mandals, 20 are identified as peri-urban zones, indicating the seamless growth of urban regions, according to G.O.No.33 issued by HMDA.

The mandals originate from the districts of Medchal, Medak, Ranga Reddy, Sanga Reddy and Yadadri Bhuvangiri. The total peri-urban area spans 554.65 sq. km across 20 mandals. The largest is Tupran in Medak (61.43 sq. km), followed by Bibi Nagar in Yadadri Bhuvangiri (60.48 sq. km), Sanga Reddy (47.72 sq. km) and Kothuru in Ranga Reddy (43.13 sq. km).

1.1. Aim and Objectives

- This research aims to evaluate the alterations in land use and land cover (LULC) within the peri-urban zone of the Hyderabad Metropolitan Region, employing delineated master plans alongside remote sensing and GIS methodologies.
- Additionally, the study seeks to conduct an accuracy assessment of classified maps.
- It also endeavors to comprehend the changes occurring in the peri-urban area over five years (2017-2022) across selected mandals.

This investigation covers the aforementioned five-year timeframe and utilises publicly available Sentinel-2 data. The selection of this particular study period was based on the accessibility of supplementary data essential for interpreting the results.

2. Literature Review

The rapid expansion of urban areas, often referred to as urban sprawl, has become a significant global concern due to its tendency to cause considerable transformations in the environment, thereby disrupting the delicate balance of land use and land cover. Understanding the trends and implications of these changes is vital for fostering sustainable urban development and efficient resource management. Remote sensing technology, along with Geographic Information Systems (GIS), has emerged as a powerful tool for observing and analysing the spatial and temporal dynamics linked to urban sprawl (Krishnaveni & Anilkumar, 2020). These technologies provide a reliable means of quickly and effectively assessing the effects of urbanisation (Maktav, 2005). The growth of metropolitan regions, driven by factors such as population increase and economic development, can lead to encroachment into agricultural zones, forests and other natural ecosystems (Ramachandra, 2012). This kind of unchecked urban expansion poses risks to the sustainability of local natural resources and adversely affects the overall quality of life within urban communities (Krishnaveni & Anilkumar, 2020). By employing remote sensing data in conjunction with GIS methodologies, researchers and decision-makers can monitor urban growth, pinpoint the causes behind changes in land use and cover and formulate strategies to alleviate the detrimental effects associated with urban sprawl. Remote sensing techniques, including satellite imagery and aerial photography, offer critical spatial data at consistent intervals that enable effective identification and monitoring of swift land-use alterations (Ramachandra, 2012).

3. Methodology

3.1. Study Area

Hyderabad (Figure 1), located in Telangana, has a Master Plan by the Hyderabad Metropolitan Development Authority (HMDA) from 2013 that outlines various land use classifications across 29 administrative divisions, including 20 peri-urban areas spanning 554.65 sq. km in Medchal, Medak,

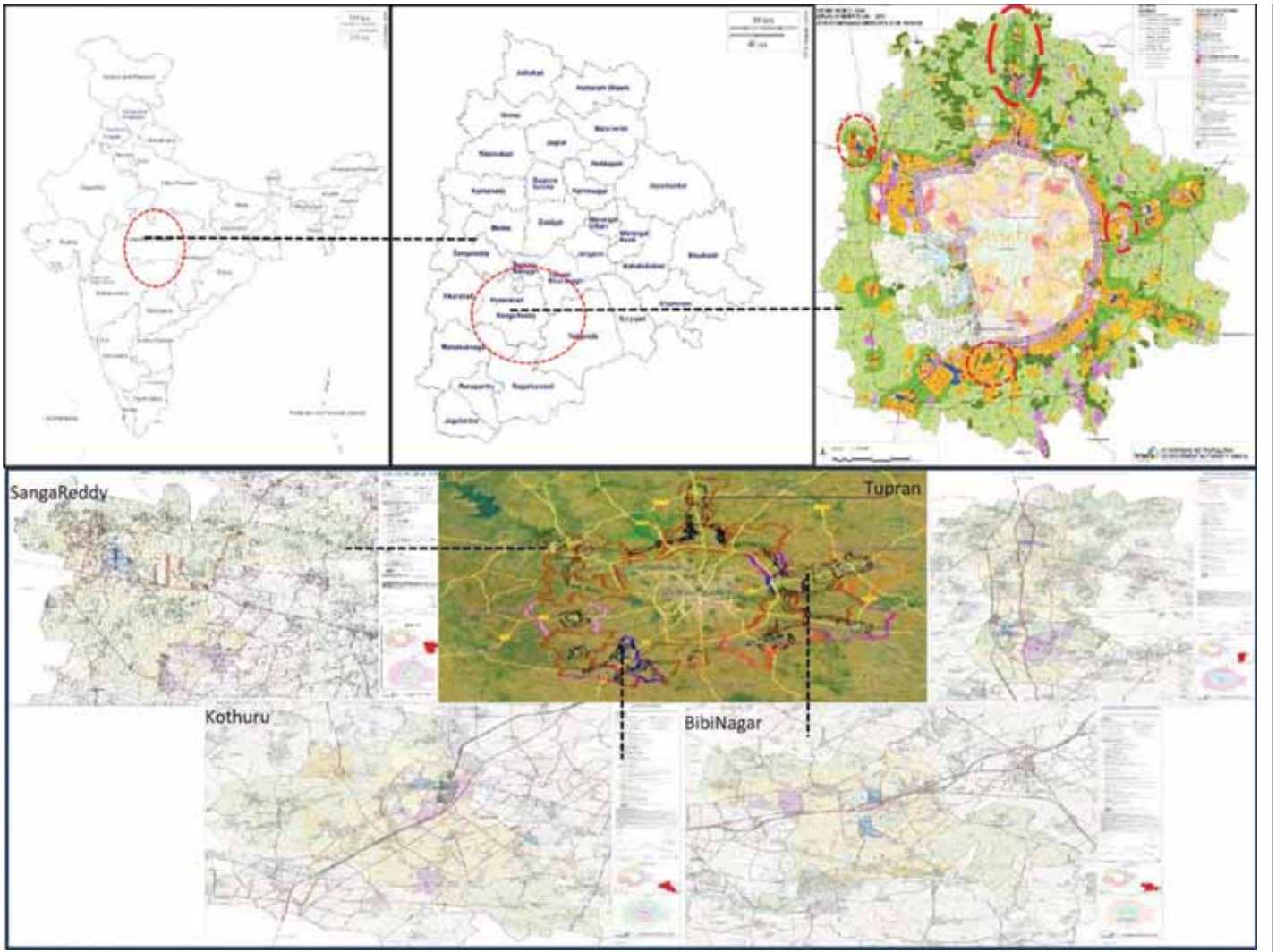


Figure 1: Location Map of Study Area
Source: Census, HMDA & Google Maps

Ranga Reddy, Sanga Reddy and Yadadri Bhuvangiri. The largest peri-urban areas are Tupran (61.43 sq. km), Bibi Nagar (60.48 sq. km), Sanga Reddy (47.72 sq. km) and Kothuru (43.13 sq. km). This research focuses on the spatial and topographical characteristics of these four areas covering 212.76 sq. km—Tupran is north, Bibinagar east, Sanga Reddy west and Kothuru south. The Land Pooling Act of 2017 has enabled the conversion of agricultural land to urban development due to population growth and urban sprawl, resulting in new residential complexes, industries, and educational facilities in these peri-urban regions.

3.2. Methodology

The study analysed land use and cover changes in Bibi Nagar, Kothuru, Sanga Reddy and Tupran Mandal using remote sensing and GIS methods. It involved data acquisition, supervised classification, accuracy assessment and change detection analysis. Master plans were digitised and georeferenced with ArcGIS for boundary establishment. Remote sensing data from Esri-Sentinel-2 Explorer was preprocessed for interpretation. GPS-based empirical data validated the LULC categorisation and assessed image accuracy. Statistical analysis calculated land use changes in the study area. A graphical representation of the methodology has been presented in Figure 2.

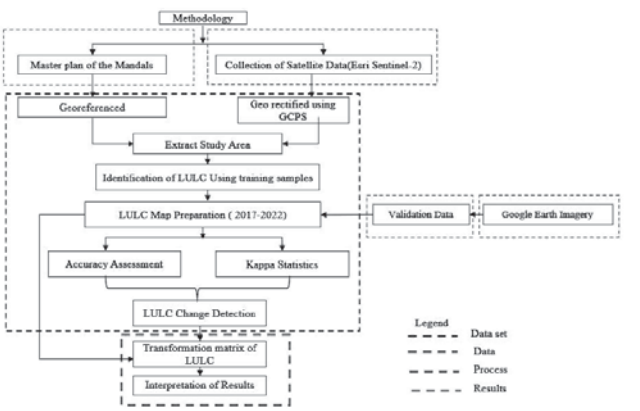


Figure 2: Methodology adopted for the Study
Source: Authors

3.3. Methods

Satellite imagery from Sentinel-2 about land cover from 2017 to 2022 was acquired and organised into three analogous bands. The master plan for four mandals, dated 2013, was geo-referenced utilising ArcGIS 10.8 and assigned the UTM WGS 84 projection. Subsequently, the geo-referenced boundaries of both the Mandal and peri-urban areas were delineated in ArcGIS 10.8 and superimposed upon the satellite data to extract spatial extent and land use/land cover (LULC) information for each Mandal.

4. Data Analysis and Findings

4.1. Database

Secondary data collected, such as the satellite images, the reports and documents for the study, are presented with details in Table 1. Satellite imagery for land use and land cover (LULC) changes was sourced from the Esri-Sentinel-2 website, chosen for its free digital archive and reliable spatial and spectral resolutions. The Esri-Sentinel-2 Land cover data covered 2017 to 2022. Utilising Microsoft's Planetary Computer, over 400,000 annual Earth observations from Sentinel-2 Level-2A images were analysed for LULC predictions across various categories. Careful selection of satellite image acquisition dates prioritised seasonal consistency and cloud-free conditions to enhance spectral signature distinction. Administrative maps of the study area were obtained from the Hyderabad Metropolitan Development Authority (HMDA) and georeferenced for analysis.

4.2. Image Processing

The global land use/land cover (LULC) map is available via Esri's Sentinel-2 imagery. It utilises Impact Observatory's deep learning model, trained on the National Geographic Society's manually annotated pixels. This model runs on Microsoft's Planetary Computer, analysing over 400,000 annual Earth observations from Sentinel-2 Level-2A images to generate LULC predictions across various categories.

4.3. Image Classification

The study area's boundary was obtained in vector format and a subset image was created. An unsupervised classification using the maximum likelihood algorithm classified the satellite images based on pixel values, grouping similar pixels into distinct classes. Each pixel was assigned to the nearest cluster center based on spectral distance. After clustering, the number of clusters was reduced to four to match the LULC classes, using field knowledge and high-resolution Google Earth imagery. The satellite images were classified into five LULC categories: built-up areas, agricultural land, range land, bare ground, flooded vegetation and water bodies, detailed in Table 2.

4.4. Assessing Accuracy

The accuracy of the Land Use and Land Cover (LULC) classification for 2022 was evaluated using ground truth observations. A total of 100 to 30 points per class were collected through visual analysis and an error matrix approach, with accuracy measured by the kappa factor. Remote sensing data from all years supported this assessment, while verification sites from 2022 were mapped onto later images for additional accuracy checks.

4.5. Change Detection

The alterations in land use and land cover (LULC) from 2017 to 2022 were analysed utilising the post-classification change detection technique within ArcGIS 10.8. This methodology was chosen to mitigate the possible influences of spectral

Table 1: Details of Data
Source: Esri, HMDA, Census of India

Satellite Data				
Sensor	**Year**	**Resolution**	**Data Format**	**Purpose**
Esri-Sentinel-2- Land cover (2017 to 2022)	2017 to 2022	10m	Geo Tiff	Land use /Landcover Analysis
Additional Data				
Master Plans of Mandals (Hyderabad Metropolitan Region)	2013		JPEG	Georeferencing, Base Layer, Boundary Delineation
Google Earth	2023		Imagery	Interpretation and Analysis
Census data	2011		Excel Format	Population Analysis

Table 2: Description of Land Use Land Cover classes
Source: Esri Sentinel-2 Land Cover

S.No.	LULC	Description
1	Agriculture Land	Crops cultivated by humans are not as tall as trees.
2	Built up	Human-made structures include major roads, rail networks, and extensive impervious surfaces like parking lots, office buildings, and homes.
3	Bare Ground	Bare ground consists of rock or soil with little to no vegetation year-round, such as exposed rock, deserts, dunes, dry salt flats, and dried lake beds.
4	Flooded Vegetation	Vegetated areas show significant water mixing for most of the year.
5	Range Land	Open areas with uniform grasses and minimal taller plants, featuring scattered plants or exposed soil and rock. Includes scrub clearings in forests that aren't noticeably taller than trees.
6	Trees	Significant clusters of tall vegetation (15 m+) with dense canopies.
7	Water bodies	Regions consistently containing water year-round, lacking sparse vegetation, rock outcrops, or structures like docks.

resolution and sensor discrepancies across various satellite imagery. Such an approach facilitates the assessment of temporal changes in land cover and quantifies the degree of transformation attributed to urban growth. The percentage of change between the specified time frames was presented accordingly:

$$\% \text{ Change} = (Af - Ai / Ai) \times 100 \quad \ldots\ldots (1)$$

Where Af signifies the area of the final year and Ai signifies the area of the initial year (Fenta et al., 2017).

4.6. Change detection and Transition matrix

Change detection assesses the modifications associated with Land Use and Land Cover (LULC) transformations within a given landscape by employing geo-referenced multi-temporal remote sensing imagery collected for the same geographical area on specified acquisition dates (Ramachandra & Kumar, 2004). The research utilised a post-classification comparison (PCC) method to identify LULC changes between two separately classified maps representing different points in time during the study period (Jensen, 2005). Although this method is widely used for comparing maps from distinct sources, it does present certain limitations. The PCC approach yields comprehensive and detailed information regarding "from-to" LULC changes, as it does not necessitate data normalisation between the two timeframes (Coppin et al. 2004; Jensen 2005; Teferi et al., 2013; Aldwaik & Pontius 2013). By applying the PCC method, a cross-tabulation matrix, also known as a LULC change transition matrix, was produced utilising overlay functions in ArcGIS.

5. Results and Discussions

5.1. Population Growth

The population across the four administrative divisions, referred to as mandals, has consistently risen over time. After the release of the master plan in 2013, each mandal has allowed for the incorporation of a maximum of 20 villages into peri-urban areas to support urban expansion. The data presented in Figure 3 and Table 3 reveal that while growth rates have diminished over the decades, overall population growth continues to rise. As these villages are part of the HMDA peri-urban region, various developmental factors such as the Outer Ring Road (ORR), Regional Ring Road (RRR) and other proposals have significantly influenced population growth alongside natural increases.

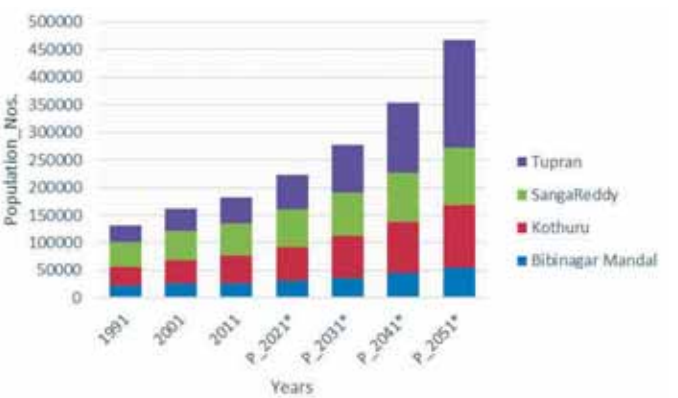


Figure 3: Population details of the Mandals
Source: Compiled by Authors

Table 3: Population Projection for the four Mandals
Source: Census of India, Compiled by Authors

Years		Mandals			
		Bibinagar	Kothuru	SangaReddy	Tupran
1991	Population	23161	33597	43258	31500
2001		25245	42488	54133	39672
2011		26300	50509	57577	47773
P_2021*		31019	61960	66646	62920
P_2031*		36915	76007	77143	86939
P_2041*		44491	93238	89294	126703
P_2051*		54600	114376	103359	195103
Average Growth Rate (1991-2011)		7	23	16	23

*Projected population calculated by the Geometrical Increase Method

5.2. Land Use Land Cover Maps Analysis of Bibinagar, Kothur, SangaReddy and Tupran

5.2.a. Bibinagar

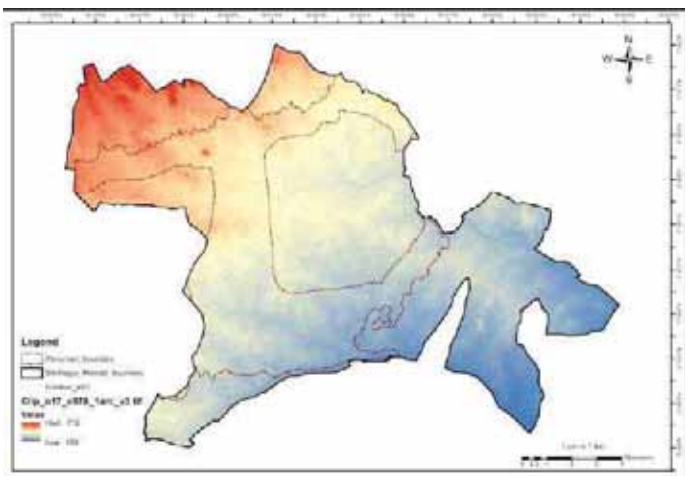


Figure 4: Topography of Bibinagar
Source: Compiled by Authors

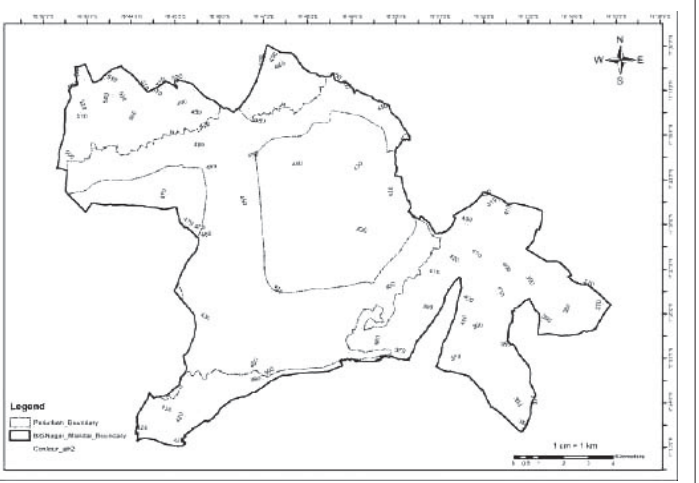
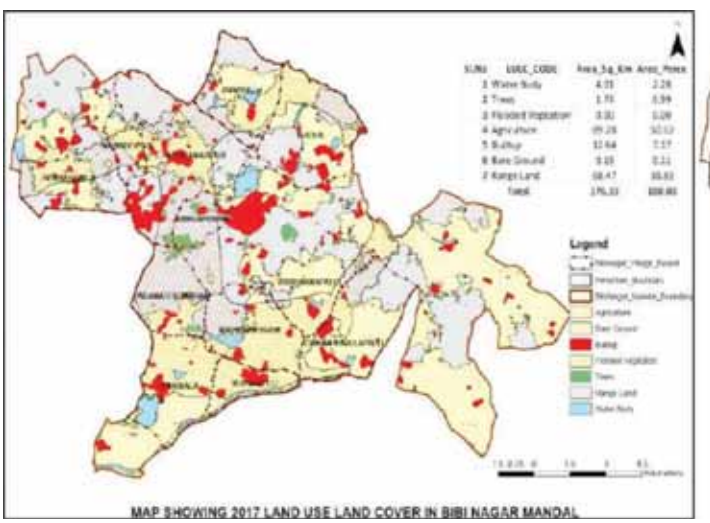


Figure 5: Slope of Bibinagar
Source: Compiled by Authors



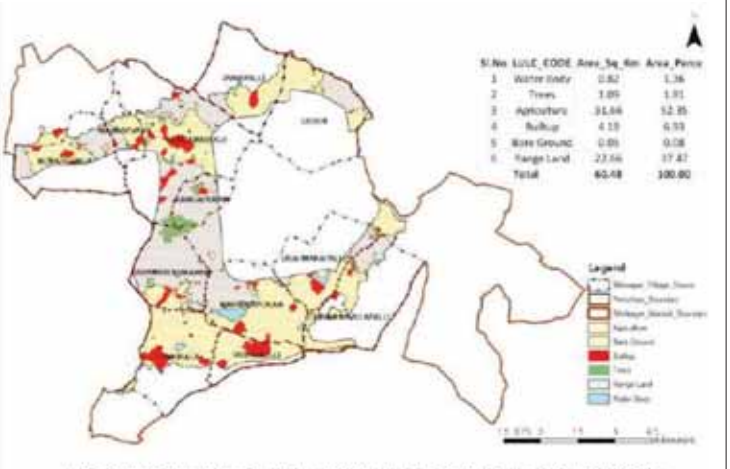


Figure 6: LULC Map (2017) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

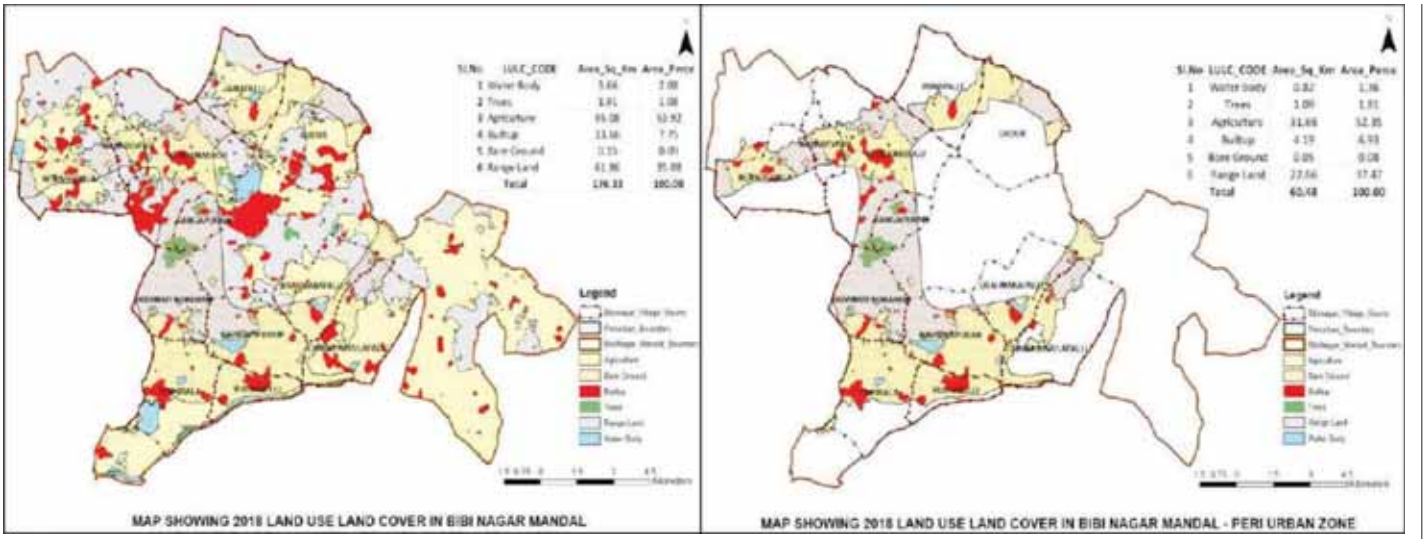


Figure 7: LULC Map (2018) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

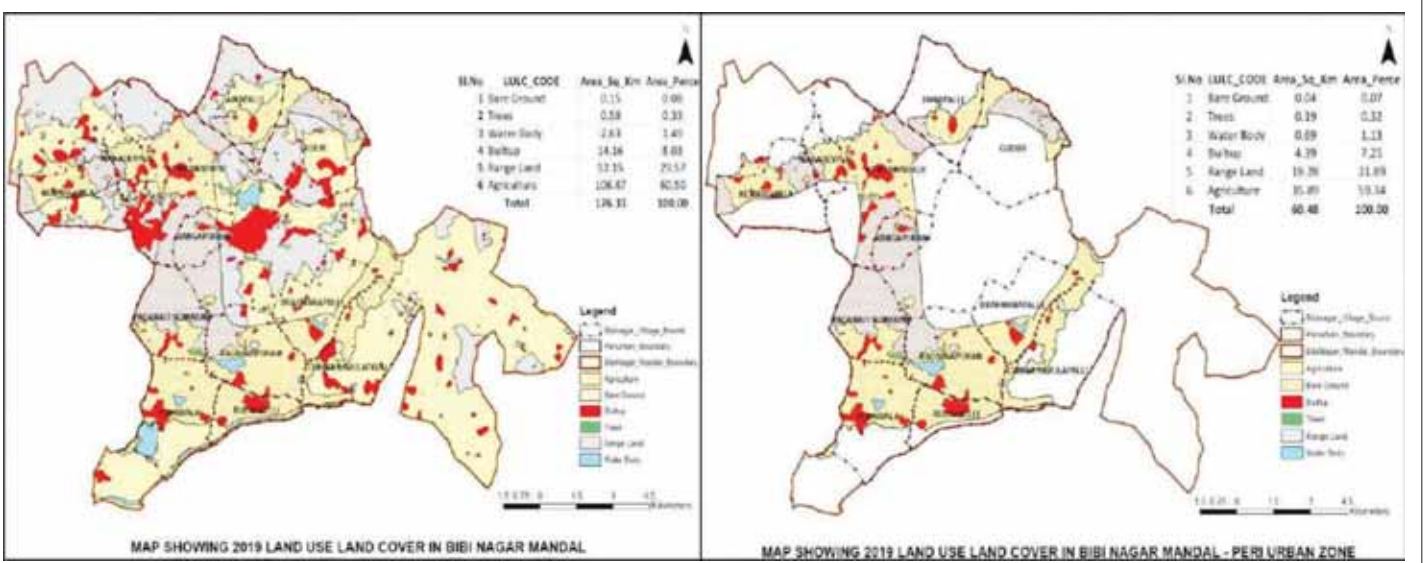


Figure 8: LULC Map (2019) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

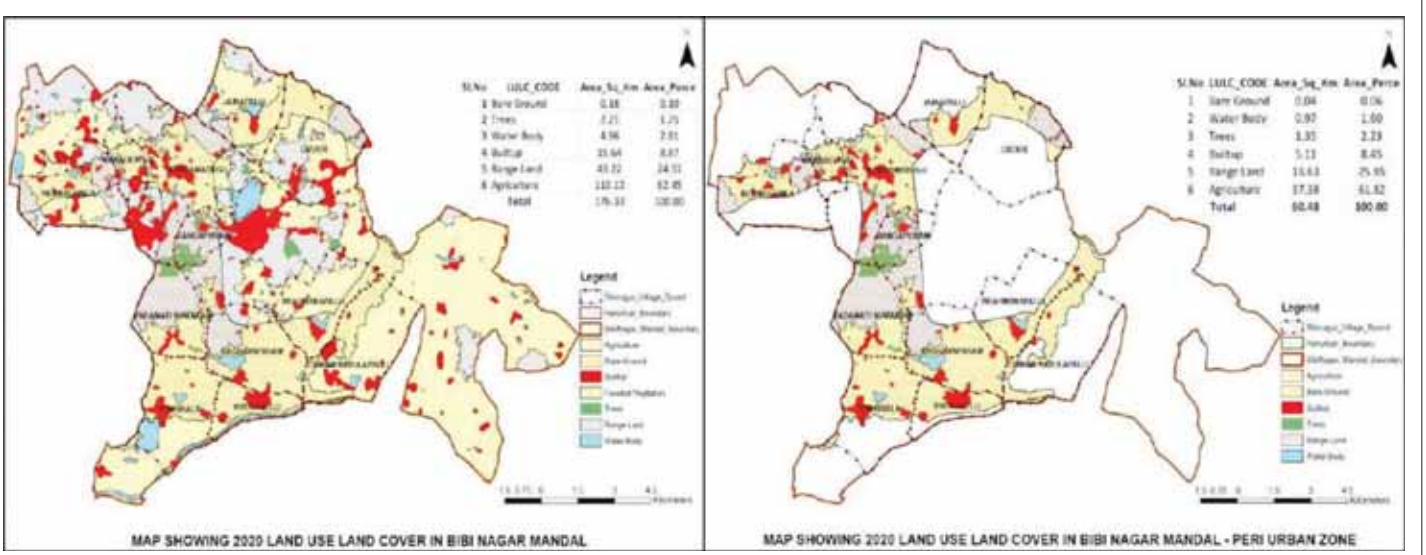


Figure 9: LULC Map (2020) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

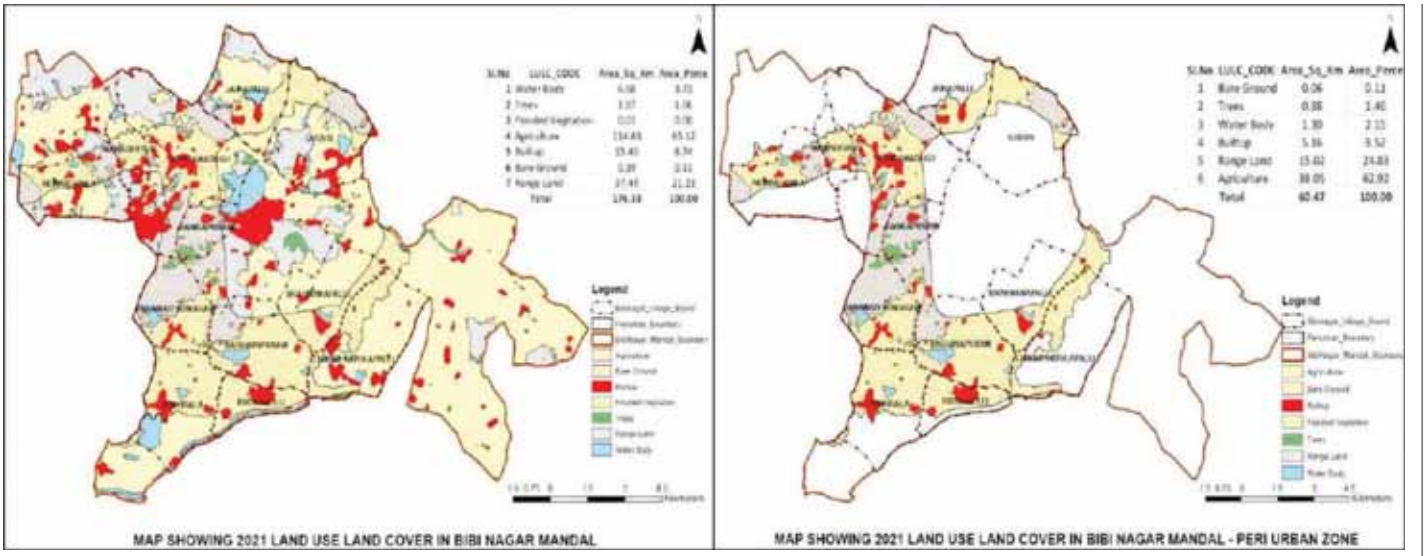


Figure 10: LULC Map (2021) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

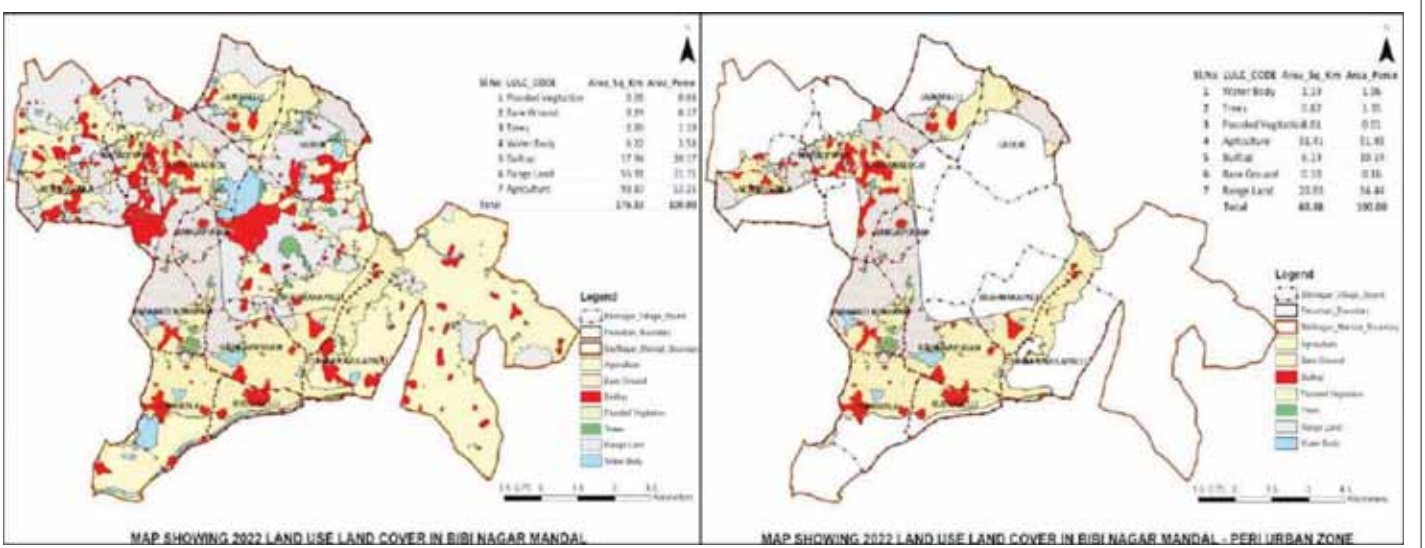


Figure 11: LULC Map (2022) of Bibinagar Mandal and Peri urban Area
Source: Compiled by Authors

5.2.b. Kothur

Figure 12: Topography of Kothur (Compiled by Authors)
Source: Compiled by Authors

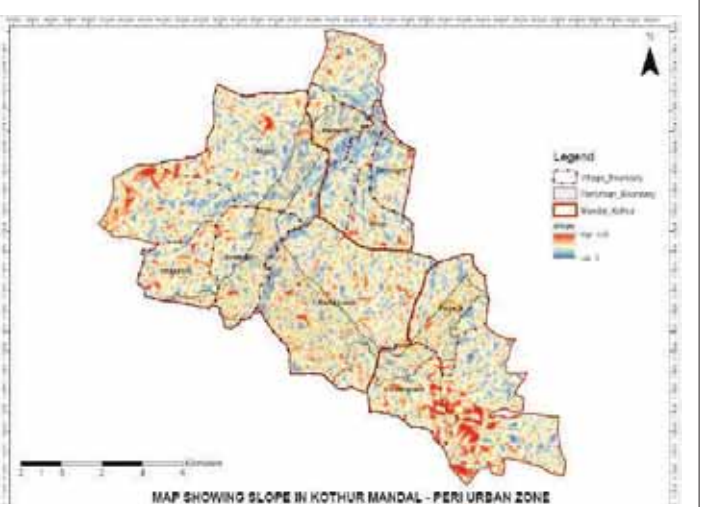


Figure 13: Slope of Kothur
Source: Compiled by Authors

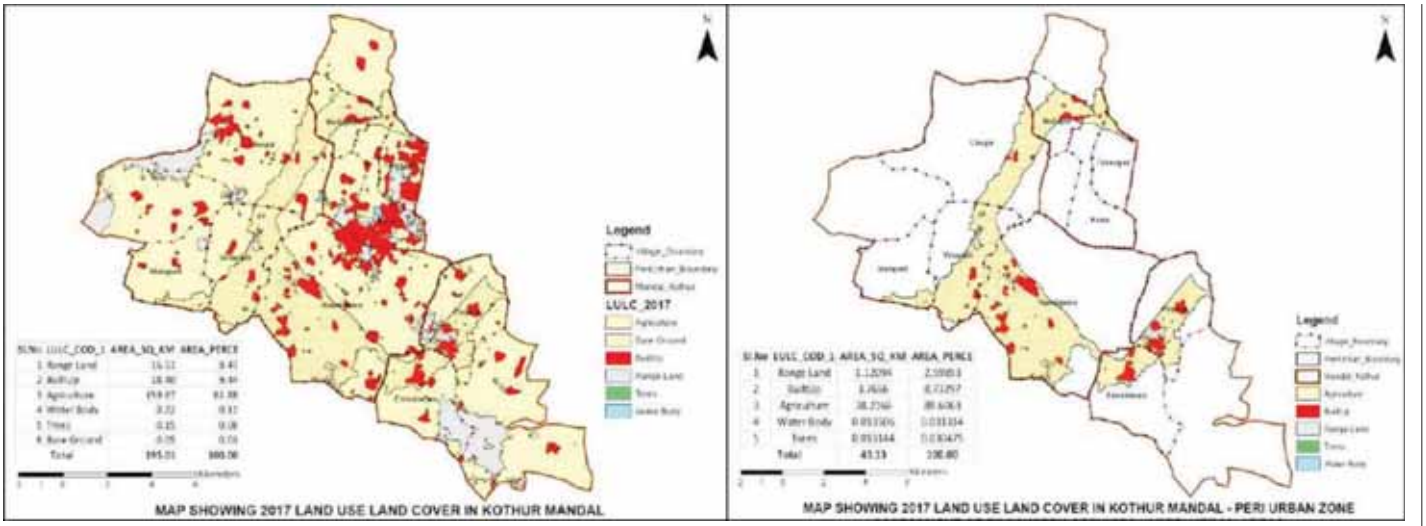


Figure 14: LULC Map (2017) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

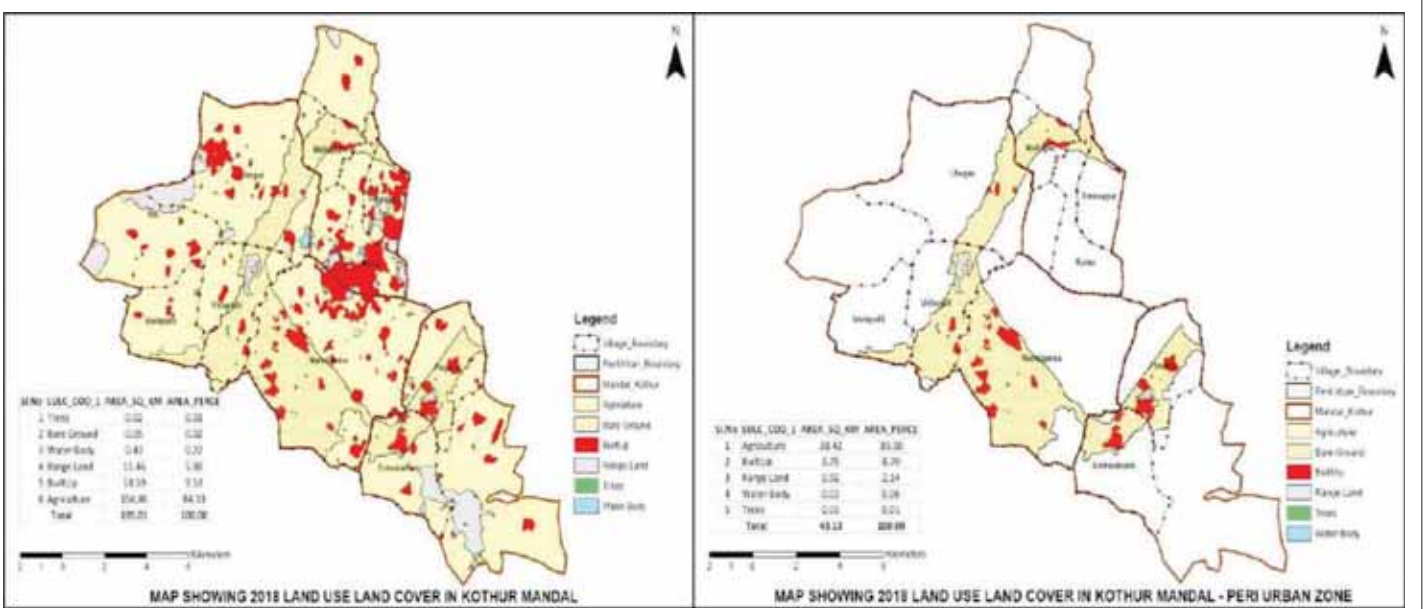


Figure 15: LULC Map (2018) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

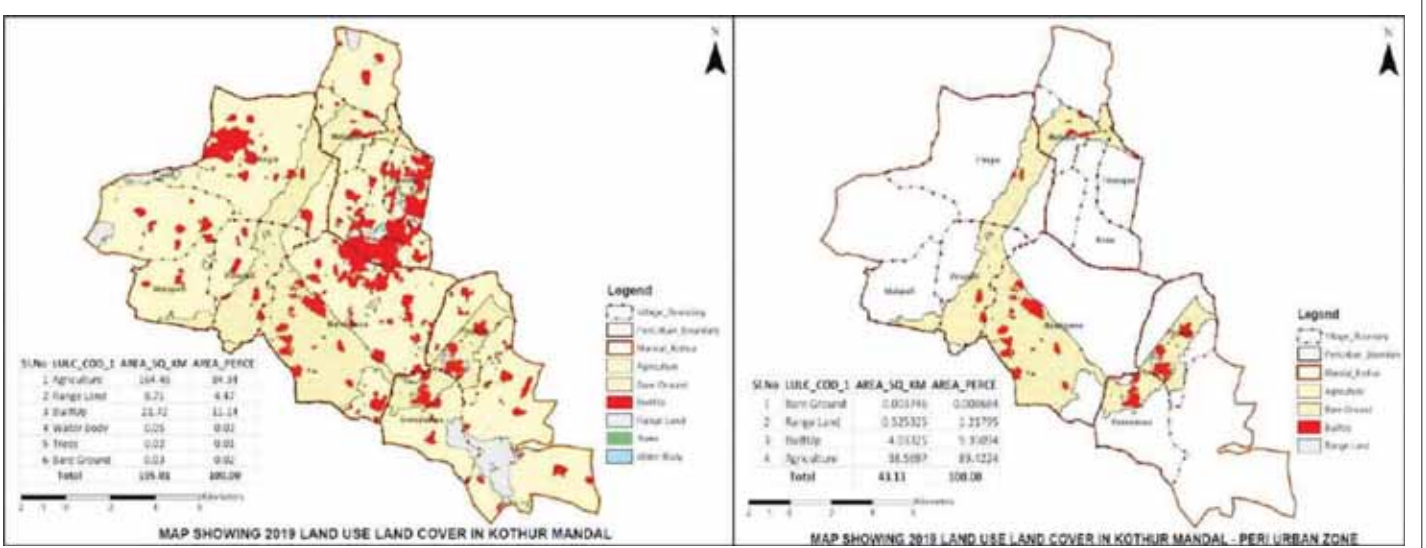


Figure 16: LULC Map (2019) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

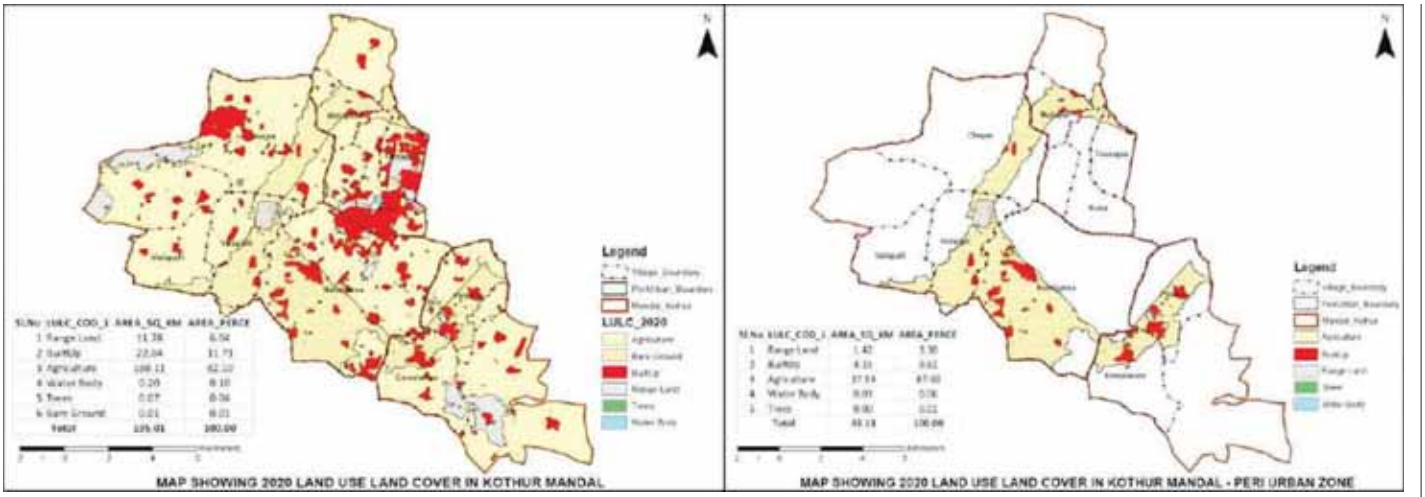


Figure 17: LULC Map (2020) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

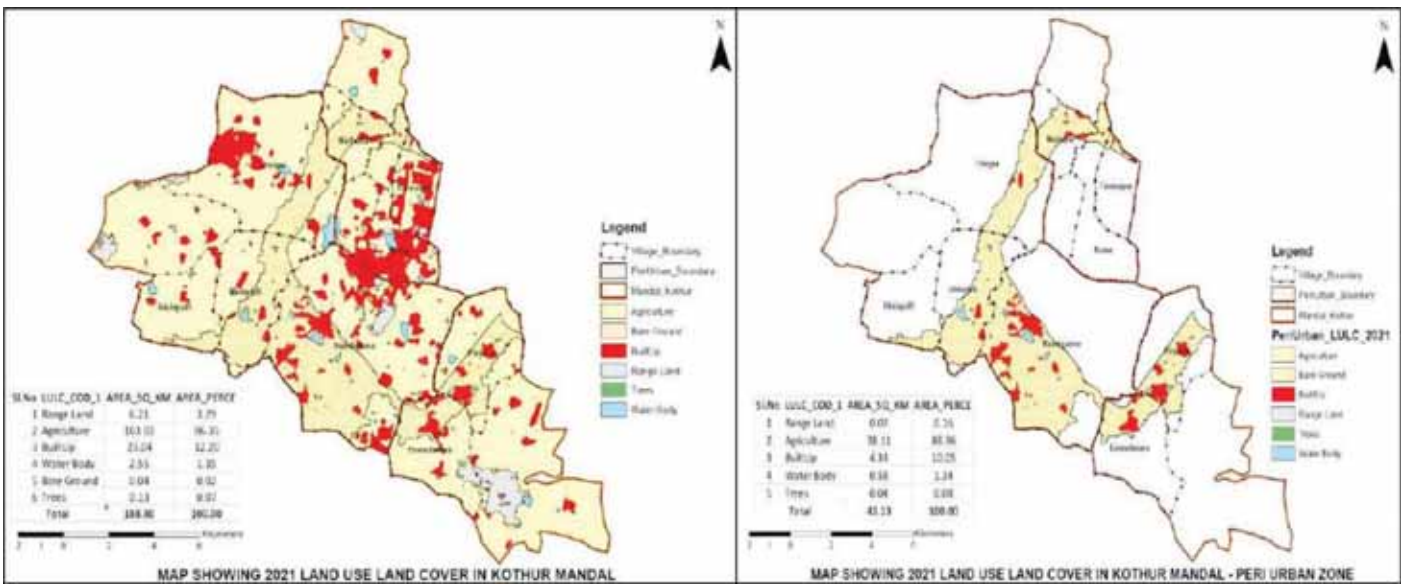


Figure 18: LULC Map (2021) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

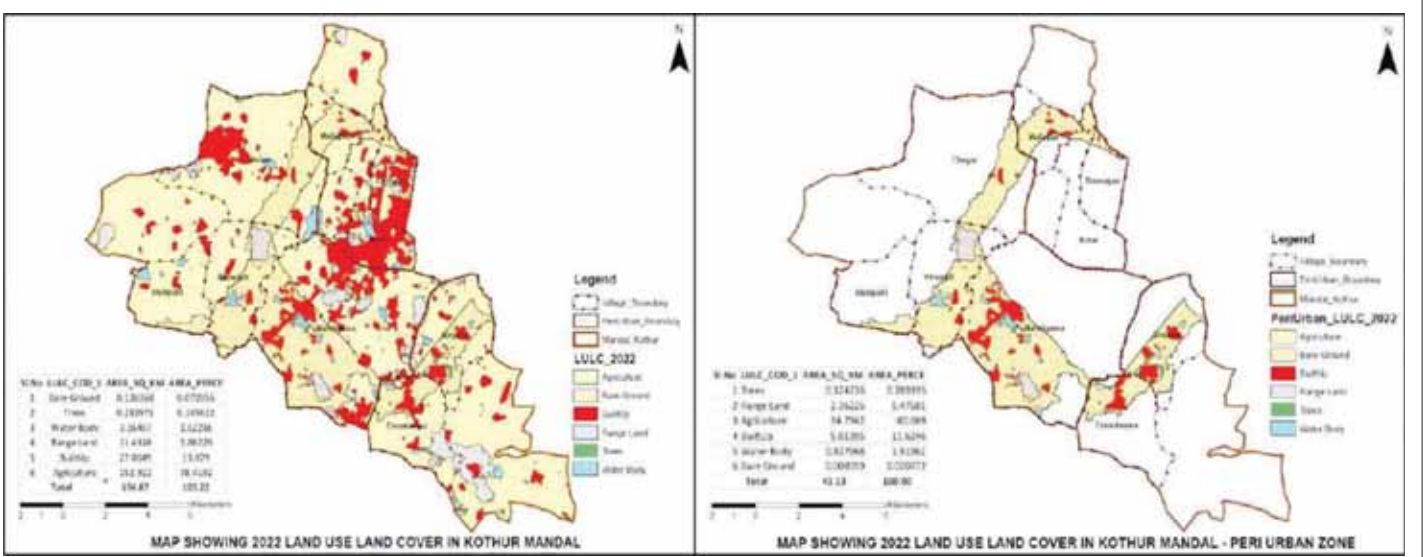


Figure 19: LULC Map (2022) of Kothur Mandal and Peri urban Area
Source: Compiled by Authors

5.2.c. Sangareddy

Figure 20: Topography of Sangareddy
Source: Compiled by Authors

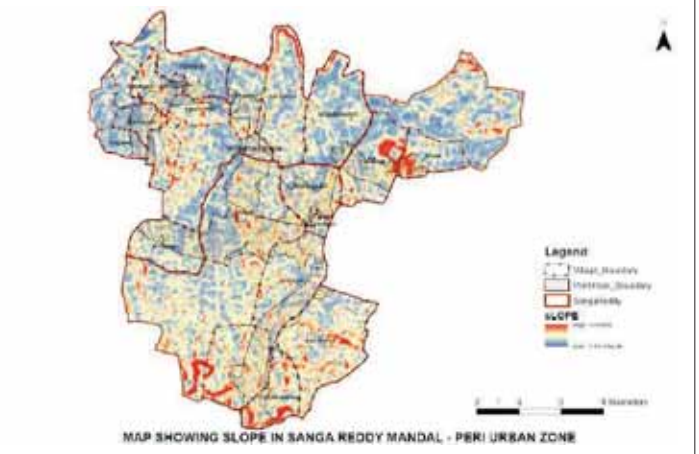


Figure 21: Slope of Sangareddy
Source: Compiled by Authors

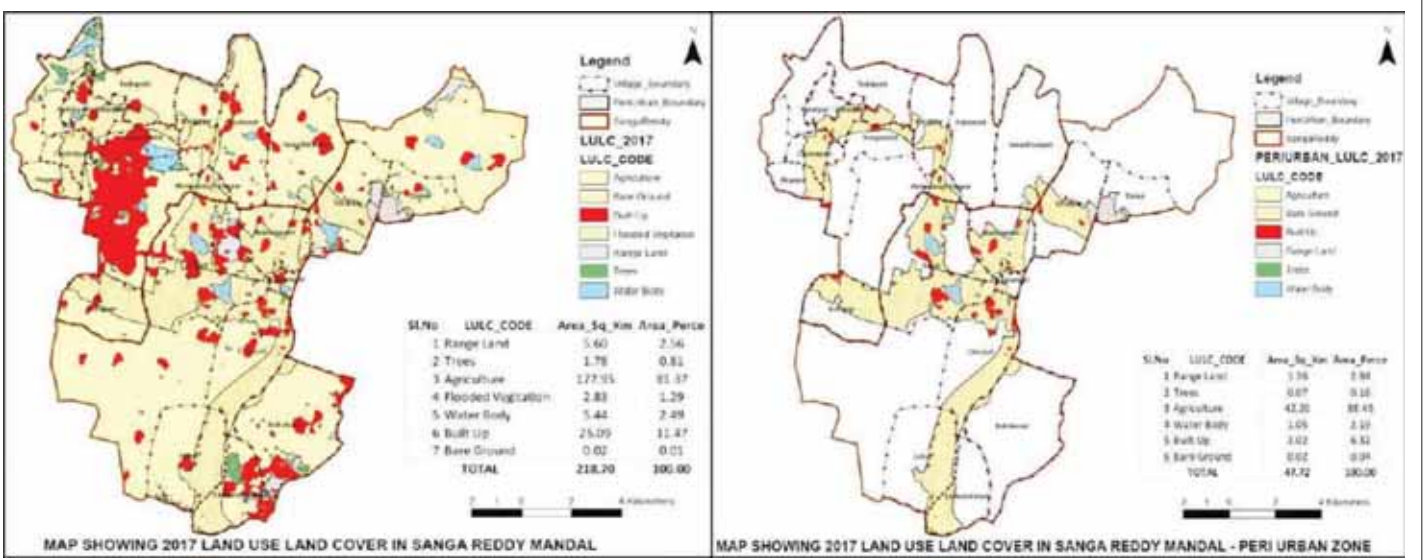


Figure 22: LULC Map (2017) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

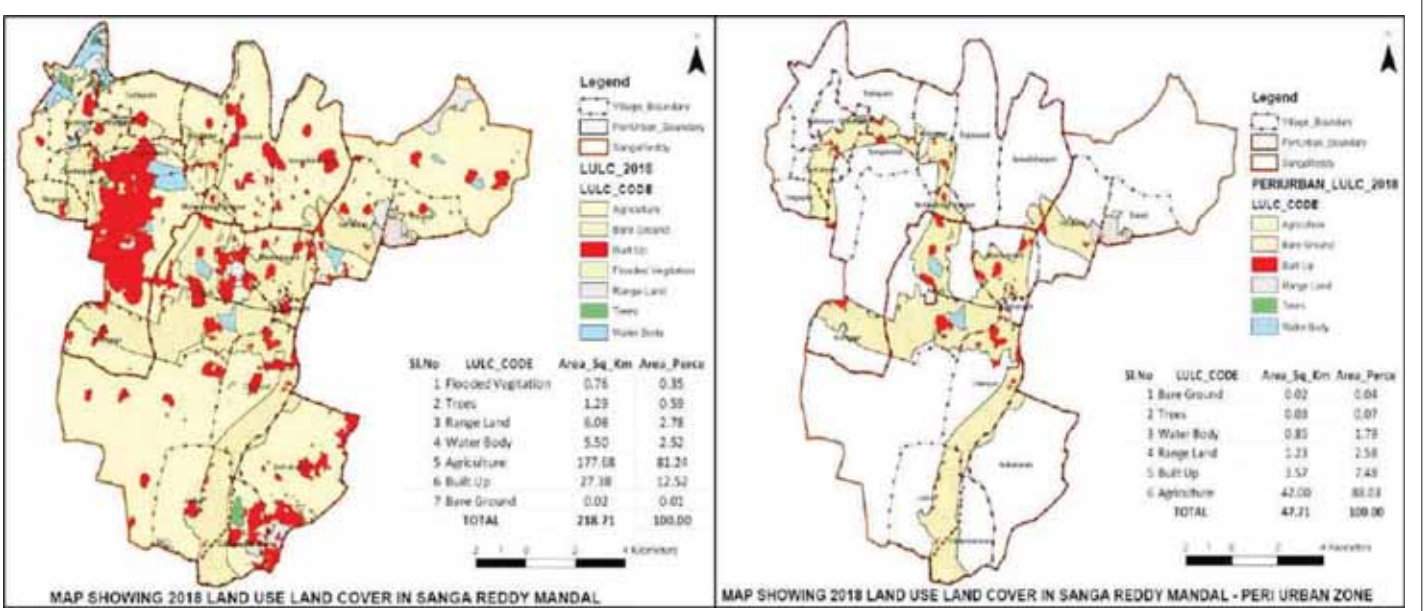


Figure 23: LULC Map (2018) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

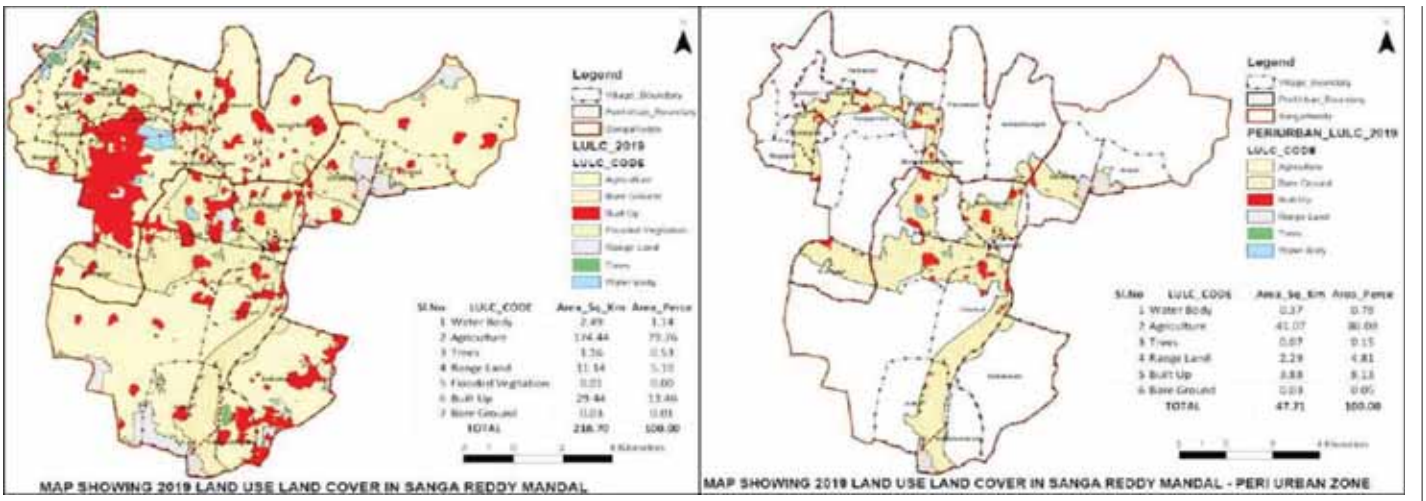


Figure 24: LULC Map (2019) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

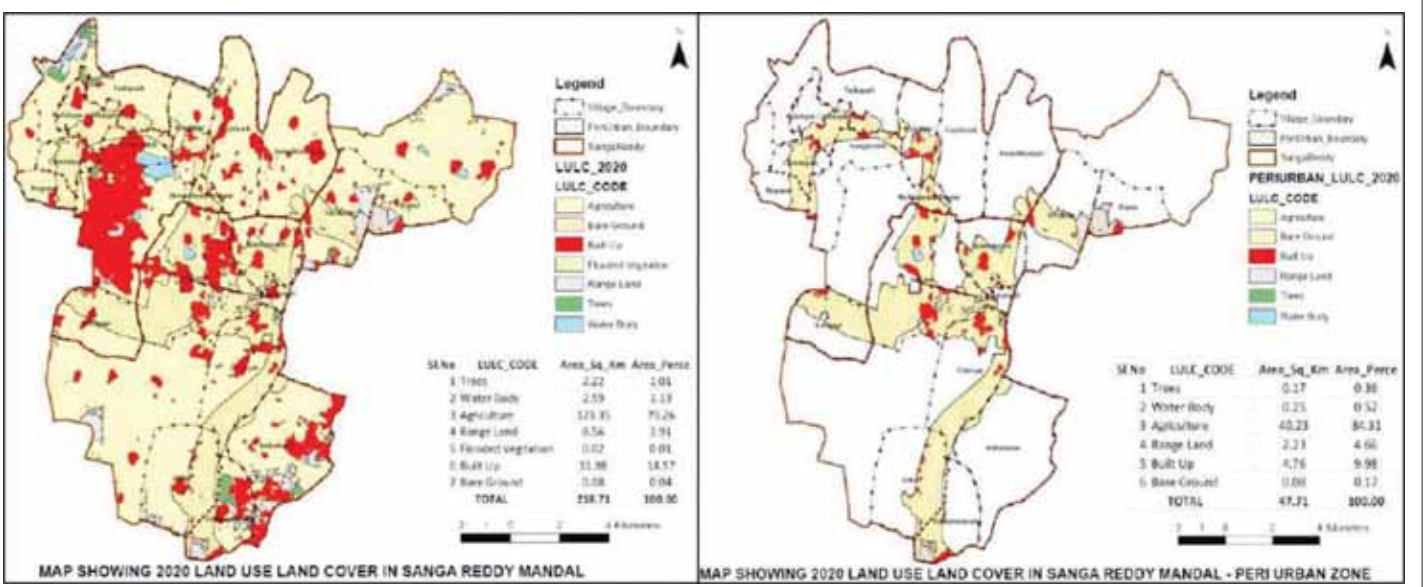


Figure 25: LULC Map (2020) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

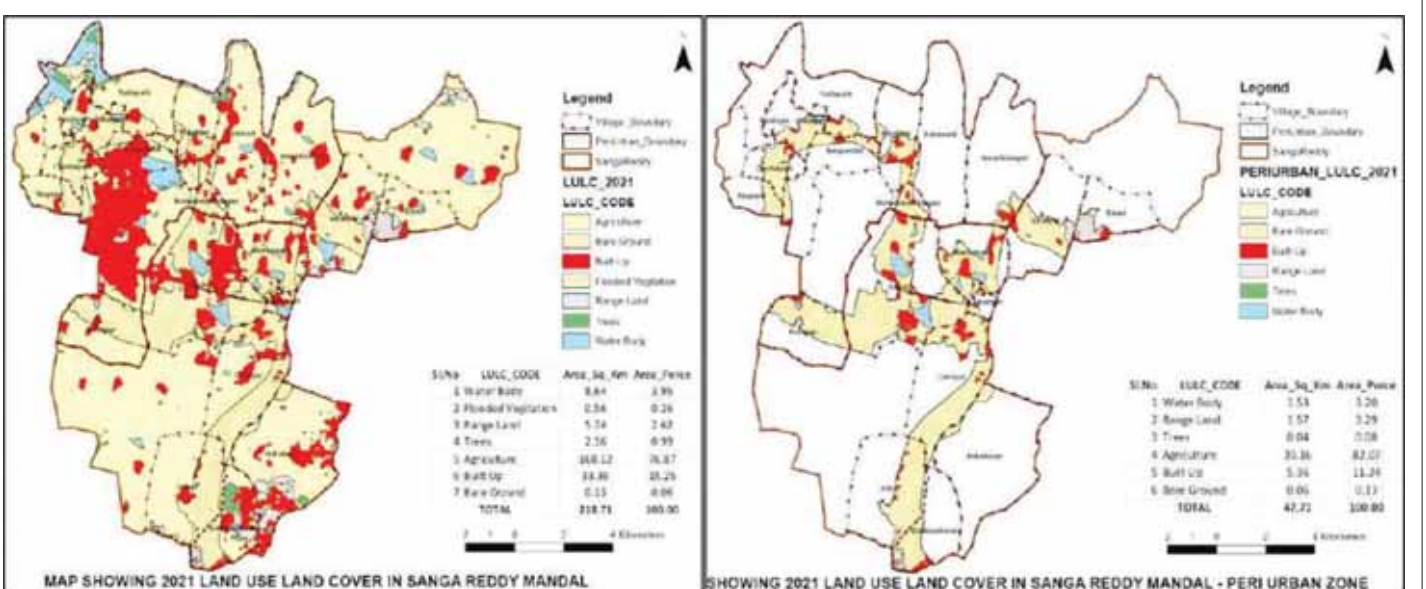


Figure 26: LULC Map (2021) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

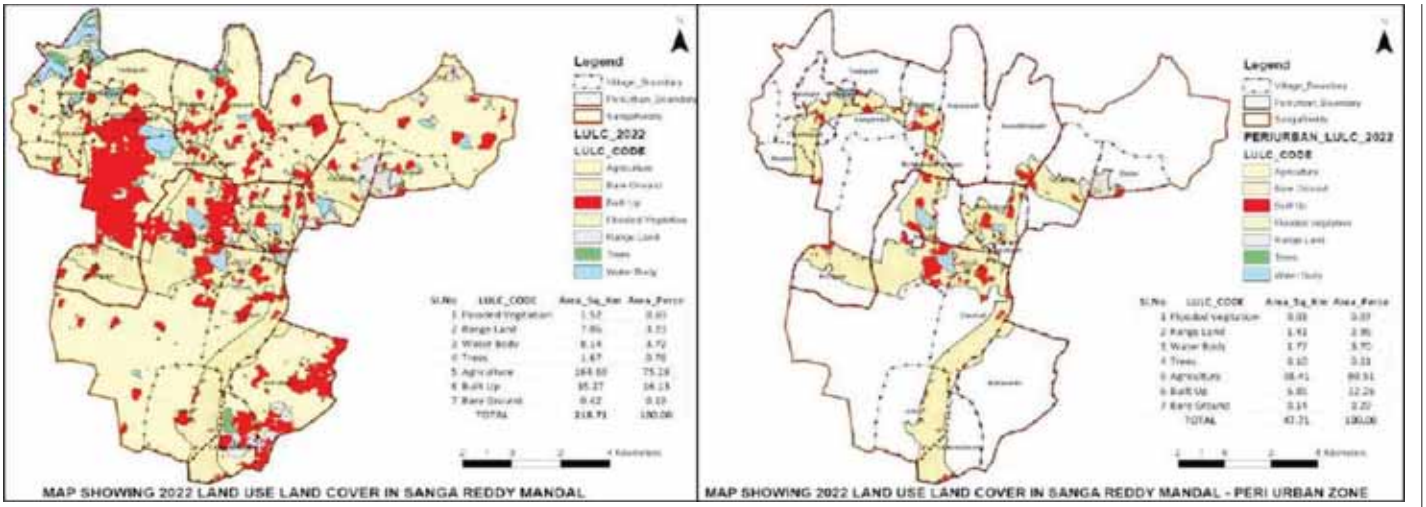


Figure 27: LULC Map (2022) of Sangareddy Mandal and Peri urban Area
Source: Compiled by Authors

5.2.d. Tupran

Figure 28: Topography of Tupran Mandal (Compiled by Authors)
Source: Compiled by Authors

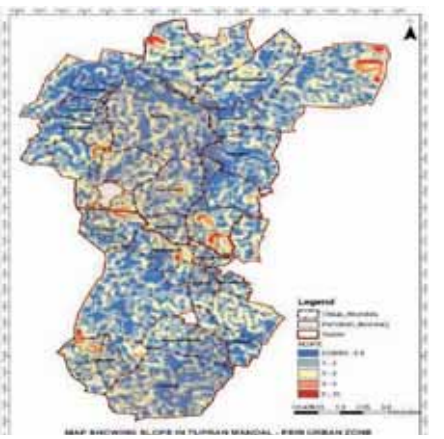


Figure 29: Slope of the Tupran Mandal
Source: Compiled by Authors

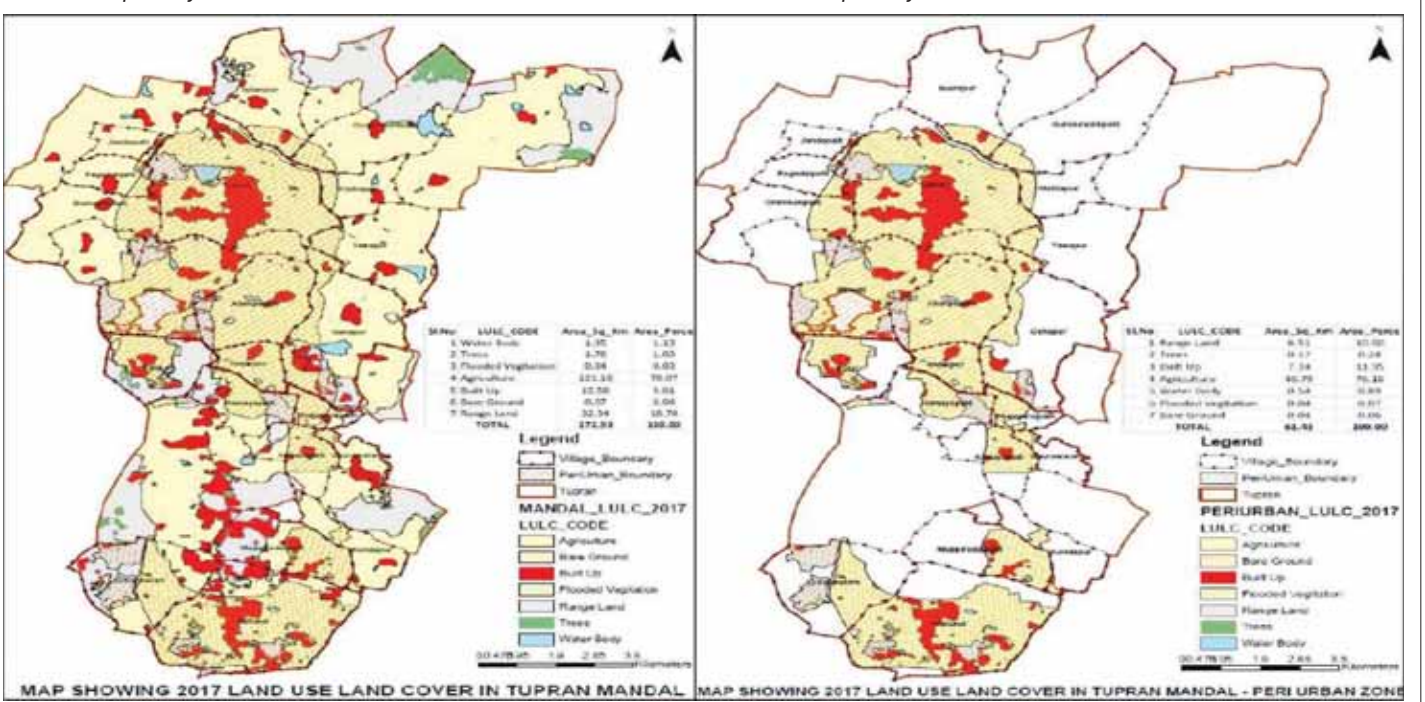


Figure 30: LULC Map (2017) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

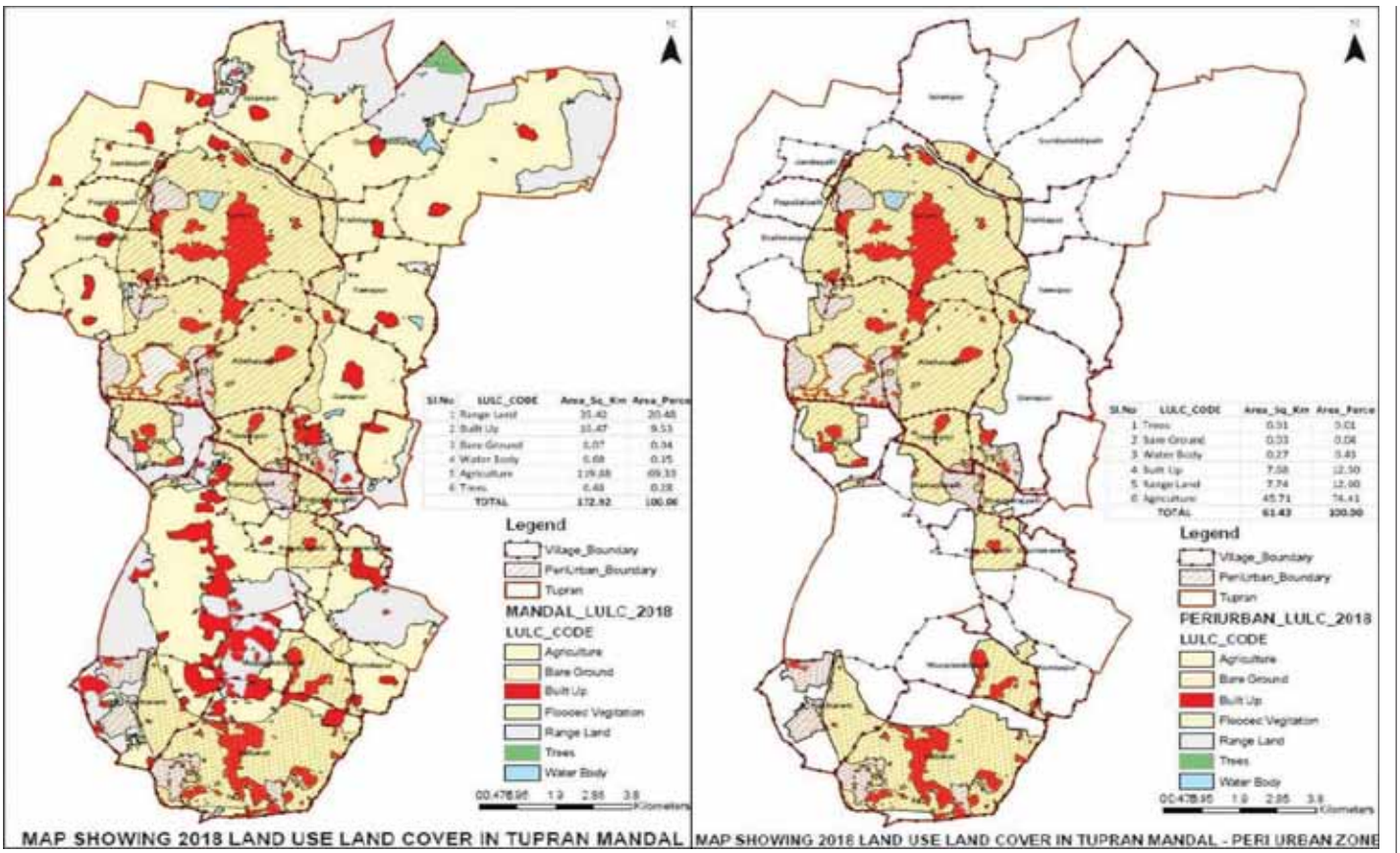


Figure 31: LULC Map (2018) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

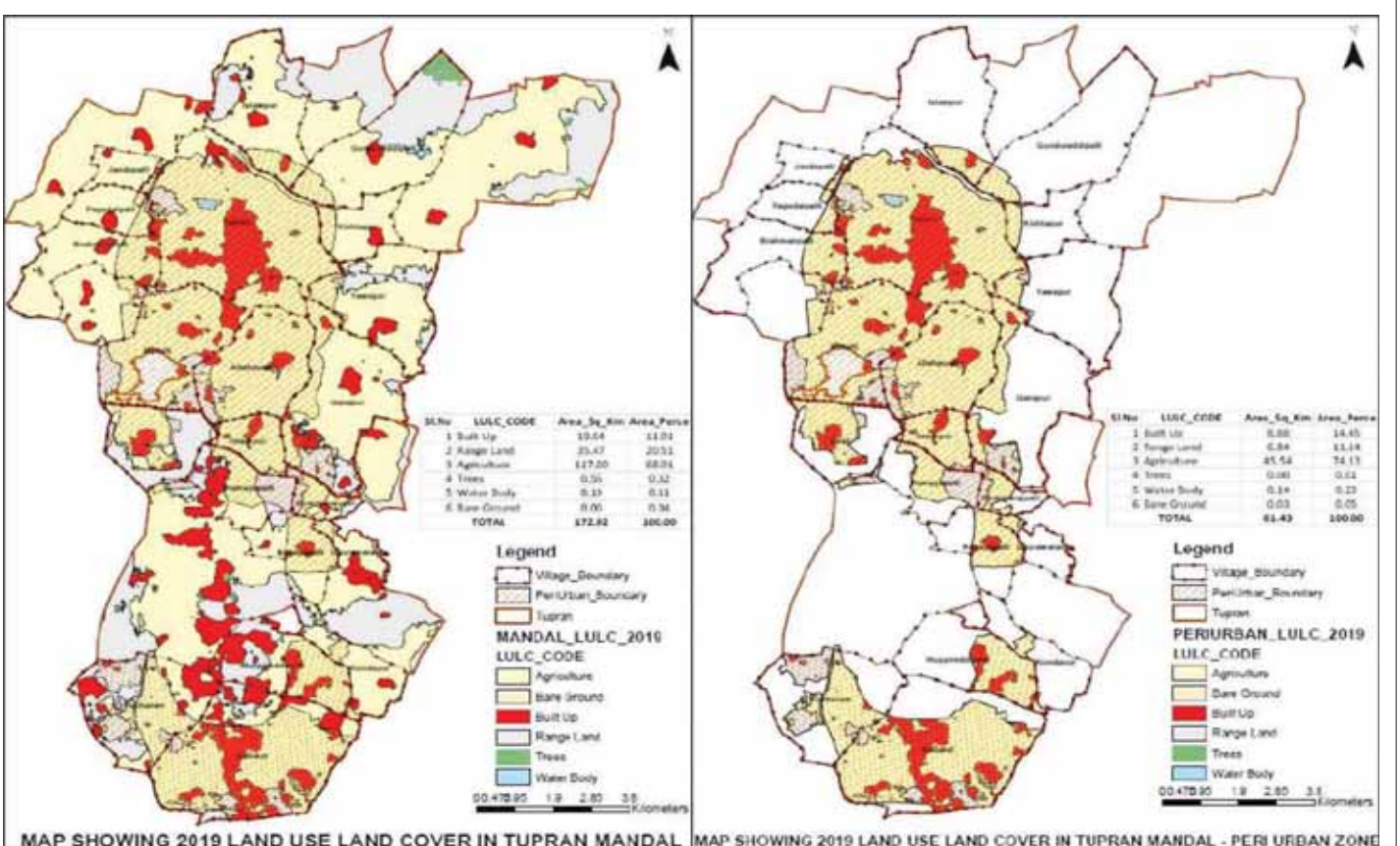


Figure 32: LULC Map (2019) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

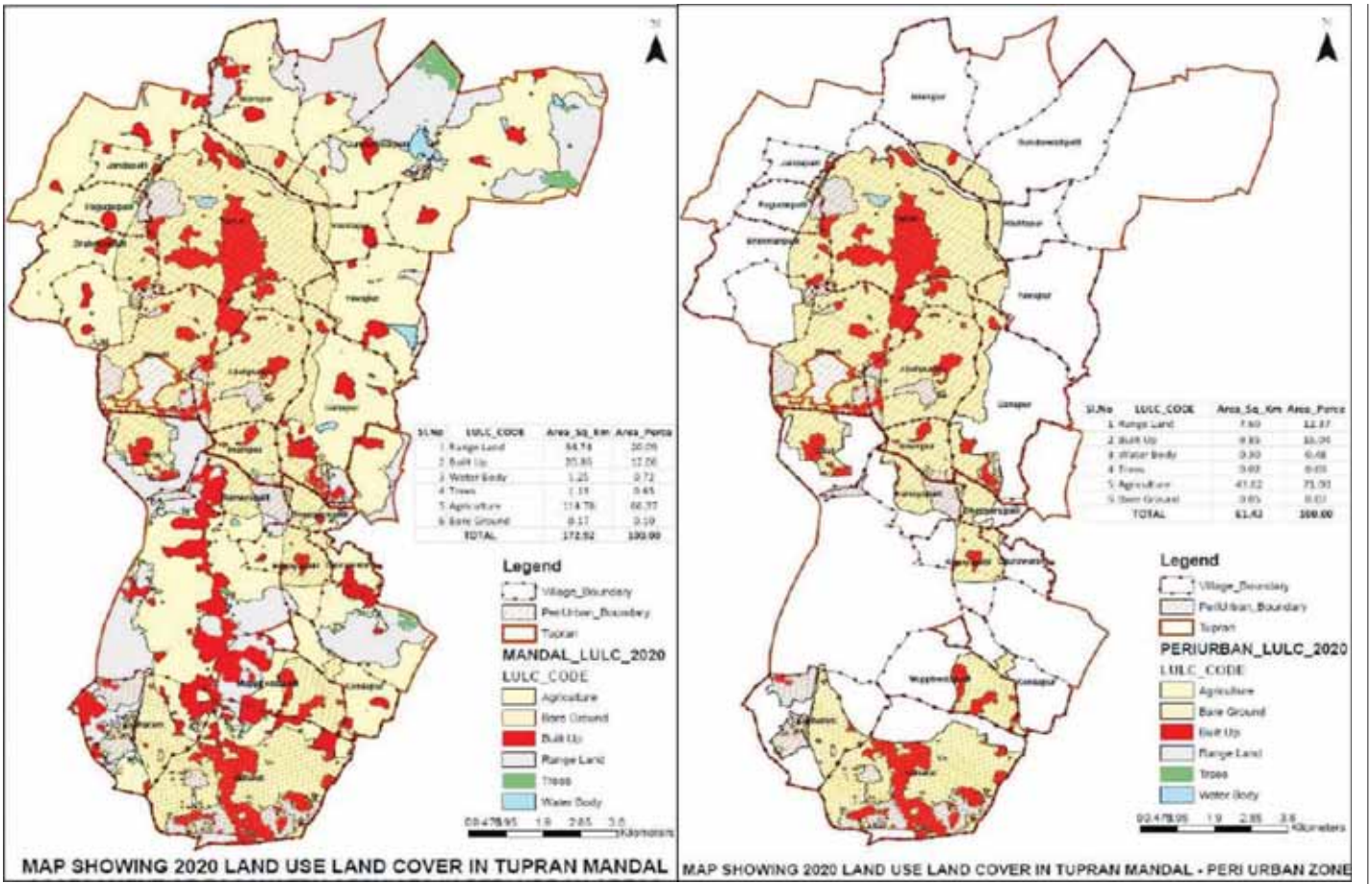


Figure 33: LULC Map (2020) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

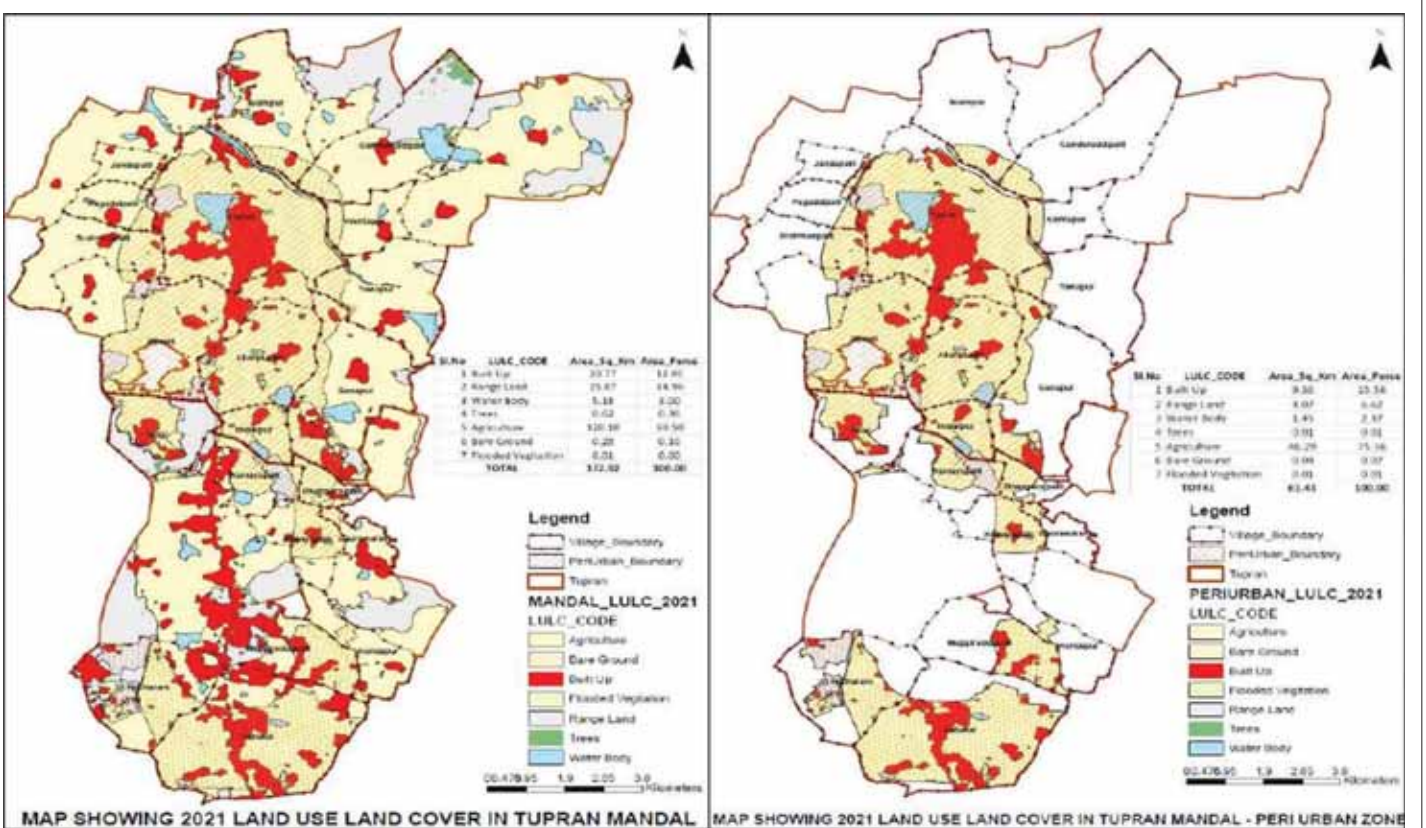


Figure 34: LULC Map (2021) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

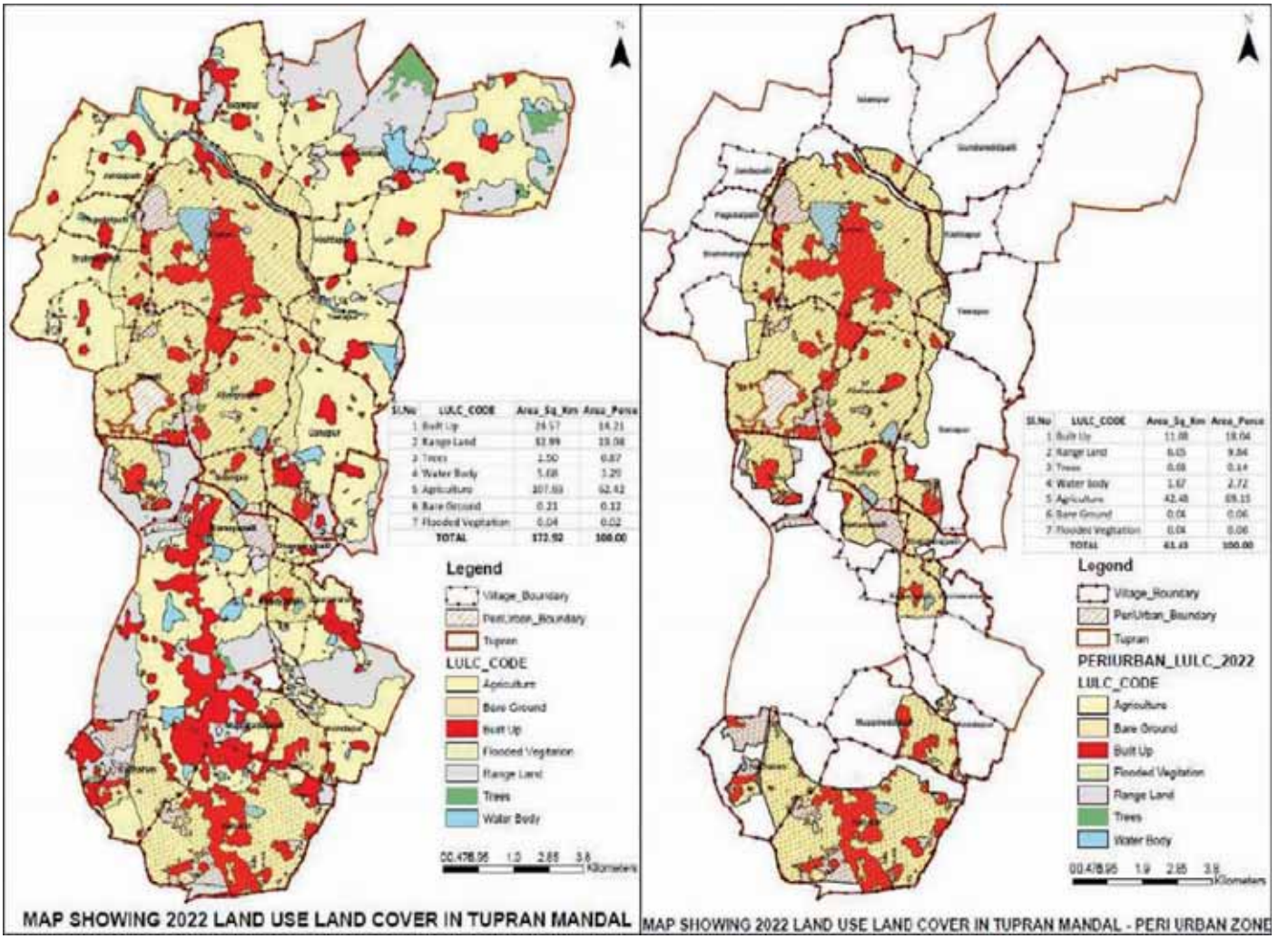


Figure 35: LULC Map (2022) of Tupran Mandal and Peri urban Area
Source: Compiled by Authors

5.3. Accuracy Assessment Analysis of LULC 2022 Map of Bibinagar, Kothur, Sangareddy, and Tupran

5.3.a Accuracy Assessment of Bibinagar

Table 4: Accuracy Assessment of Bibinagar LULC 2022 Map
Source: Compiled by Authors

LULC	Agriculture	Bare Ground	Built up	Range land	Trees	Water body	Total (User)
Agriculture	14	4	1	4	0	0	23
Bare Ground	0	1	0	0	0	0	1
Built up	0	0	37	0	0	0	37
Range land	0	1	2	15	0	0	18
Trees	6	1	0	0	13	0	20
Water body	0	0	0	0	0	11	11
Total (Producer)	20	7	40	19	13	11	110
Overall Accuracy (%)	82						
Kappa Coefficient	0.77						

5.3.b Accuracy Assessment of Kothur

Table 5: Accuracy Assessment of Kothur LULC 2022 Map
Source: Compiled by Authors

LULC	Agriculture	Bare ground	Built up	Range land	Trees	Water body	Total (User)	User Accuracy (%)
Agriculture	73	37	21	10	0	0	141	51.8
Bare ground	0	8	1	0	0	0	9	88.9
Built up	0	2	166	4	0	0	172	96.5
Range land	10	25	15	47	5	0	102.0	46.1
Trees	7	0	0	3	21	0	31.0	70.0
Water body	0	18	0	6	0	53	77	70.0
Total (Producer)	90	90	203	70	26	53	532	
Producer Accuracy (%)	81.00	8.89	81.77	67.14	80.77	100.00		
Overall Accuracy (%)	69.00							
Kappa Coefficient	0.63							

5.3.c Accuracy Assessment of Sangareddy

Table 6: Accuracy Assessment of Sangareddy LULC 2022 Map
Source: Compiled by Authors

LULC	Agriculture	Bare Ground	Built up	Flooded Vegetation	Range land	Trees	Water body	Total (User)	User Accuracy (%)
Agriculture	77	26	3	4	9	0	0	119	60.0
Bare Ground	0	27	0	0	0	0	0	27	100.0
Built up	5	3	243	0	1	3	0	255	95.0
Flooded Vegetation	0	0	0	32	0	0	0	32	100.0
Range land	0	15	4	3	44	0	0	66	63.0
Trees	0	0	0	0	0	41	0	41	100.0
Water body	0	4	0	4	0	0	65	73	89.0
Total (Producer)	82	75	250	43	54	44	65	613	
Producer Accuracy (%)	94	36	97	74.00	81	93	100		
Overall Accuracy (%)	86.00								
Kappa Coefficient	0.82								

5.3.d Accuracy Assessment of Tupran

Table 7: Accuracy Assessment of Tupran LULC 2022 Map
Source: Compiled by Authors

Accuracy Assessment of LULC of 2022 Map									
LULC	**Agriculture**	**Bare Ground**	**Built up**	**Flooded Vegetation**	**Range land**	**Trees**	**Water body**	**Total (User)**	**User Accuracy (%)**
Agriculture	32	17	4	0	8	0	0	61	52.5
Bare Ground	0	0	0	0	0	0	0	0	0.0
Built up	0	4	57	0	2	0	0	63	90.5
Flooded Vegetation	0	0	0	0	0	0	0	0	0.0
Range land	0	17	0	0	42	0	0	59	71.2
Trees	1	0	0	0	0	10	0	11	90.9
Water body	0	1	0	0	0	0	31	32	96.9
Total (Producer)	33	39	61	0	52	10	31	226	
Producer Accuracy (%)	54.10	0.00	90.48	0.00	71.19	90.91	96.88		
Overall Accuracy (%)	76.00								
Kappa Coefficient	0.69								

5.4. Change Detection Analysis

5.4. a Change Detection Analysis of Bibinagar

Table 8: Change Detection Analysis of Bibinagar
Source: Compiled by Authors

LULC		2017	2018	2019	2020	2021	2022	% of Annual Change Rate	Inference
Agriculture	Area (km2)	31.4	31.66	35.9	37.4	38.05	31.41	0.11	Increase
	%	51.9	52.35	59.3	61.8	62.91	51.93		
Range Land	Area (km2)	23.2	22.66	19.3	15.6	15.02	20.83	-10.33	Decrease
	%	38.4	37.47	31.88	25.8	24.83	34.44		
Built up	Area (km2)	4.04	4.19	4.39	5.11	5.16	6.13	51.79	Increase
	%	6.68	6.928	7.26	8.45	8.53	10.14		
Trees	Area(km2)	1	1.09	0.19	1.35	0.88	0.82	-17.57	Decrease
	%	1.65	1.802	0.31	2.23	1.46	1.36		
Water Body	Area (km2)	0.76	0.82	0.69	0.97	1.3	1.19	56.34	Increase
	%	1.26	1.356	1.14	1.6	2.15	1.97		
Bare Ground	Area (km2)	0.07	0.05	0.04	0.04	0.06	0.1	142.85	Increase
	%	0.12	0.083	0.07	0.07	0.1	0.17		
Flooded Vegetation	Area (km2)	0	0	0	0	0	0.01		
	%	0	0	0	0	0	0.02		

5.4.b. Change Detection Analysis of Kothur

Table 9: Change Detection Analysis of Kothur
Source: Compiled by Authors

LULC	Units	2017	2018	2019	2020	2021	2022	% of Annual Change Rate	Inference
Agriculture	Area (km2)	38.217	38.42	38.57	37.53	38.11	34.79	-8.96	Decrease
	%	88.61	89.08	89.42	87.02	88.36	80.67		
Range Land	Area (km2)	1.12	0.92	0.53	1.42	0.07	2.36	110.76	Increase
	%	2.60	2.14	1.22	3.30	0.16	5.48		
Builtup	Area (km2)	3.77	3.75	4.03	4.15	4.34	5.01	33.1	Increase
	%	8.73	8.70	9.35	9.61	10.05	11.62		
Trees	Area(km2)	0.01	0.01	0.00	0.00	0.04	0.12	866.66	Increase
	%	0.03	0.01	0.00	0.01	0.08	0.29		
Water Body	Area (km2)	0.01	0.03	0.00	0.03	0.58	0.83	6300	Increase
	%	0.03	0.06	0.00	0.06	1.34	1.92		
Bare Ground	Area (km2)	0	0	0	0	0	0.01	0	----
	%	0		0.00	0	0	0.02		

5.4. c. Change Detection Analysis of Sangareddy

Table 10: Change Detection Analysis of Sangareddy
Source: Compiled by Authors

LULC		Years						% of Annual Change Rate	Inference
		2017	2018	2019	2020	2021	2022		
Agriculture	Area (km2)	42.20	42.00	41.07	40.23	39.16	38.41	-8.97	Decrease
	%	88.45	88.03	86.08	84.31	82.07	80.51		
Bare Ground	Area (km2)	0.02	0.02	0.03	0.08	0.06	0.14	625.00	Increase
	%	0.04	0.04	0.05	0.17	0.13	0.29		
Built Up	Area (km2)	3.02	3.57	3.88	4.76	5.36	5.85	93.98	Increase
	%	6.32	7.48	8.13	9.98	11.24	12.26		
Flooded Vegetation	Area(km2)	0.00	0.00	0.00	0.00	0.00	0.03	0.00	----
	%	0.00	0.00	0.00	0.00	0.00	0.00		
Range land (Grassland)	Area (km2)	1.36	1.23	2.29	2.23	1.57	1.41	4.22	Increase
	%	2.84	2.58	4.81	4.66	3.29	2.96		
Trees	Area (km2)	0.07	0.03	0.07	0.17	0.04	0.10	31.25	Increase
	%	0.16	0.07	0.15	0.36	0.08	0.21		
Water Body	Area (km2)	1.05	0.85	0.37	0.25	1.53	1.77	68.95	Increase
	%	2.19	1.79	0.78	0.52	3.20	3.70		

5.4.d Change Detection Analysis of Tupran

Table 11: Change Detection Analysis of Tupran
Source: Compiled by Authors

LULC		Years						% of Annual Change Rate	Inference
		2017	2018	2019	2020	2021	2022		
Agriculture	Area (Km2)	46.79	45.71	45.54	43.62	46.29	42.48	-9.20	Decrease
	%	76.16	74.41	74.13	71.00	75.36	69.15		
Bare Ground	Area (Km2)	0.04	0.03	0.03	0.05	0.04	0.04	0.00	----
	%	0.06	0.04	0.05	0.07	0.07	0.06		
Built Up	Area (Km2)	7.34	7.68	8.88	9.85	9.56	11.08	50.96	Increase
	%	11.95	12.50	14.45	16.04	15.56	18.04		
Flooded Vegetation	Area (Km2)	0.04	0.00	0.00	0.00	0.01	0.04	0.00	----
	%	0.07	0.00	0.00	0.00	0.01	0.06		
Range land (Grassland)	Area (Km2)	6.51	7.74	6.84	7.6	4.07	6.05	-7.16	Decrease
	%	10.60	12.60	11.14	16.04	6.62	9.84		
Trees	Area (Km2)	0.17	0.01	0	0.02	0.01	0.08	-50.00	Decrease
	%	0.28	0.01	0.01	0.03	0.01	0.14		
Water Body	Area (Km2)	0.54	0.27	0.14	0.3	1.45	1.67	205.61	Increase
	%	0.89	0.43	0.23	0.48	2.37	2.72		

5.5 Transition Matrix Analysis LULC 2022 Map of Bibinagar, Kothur, Sangareddy, and Tupran

5.5.a Transition Matrix of Bibinagar

Table 12: Transition Matrix of Bibinagar
Source: Compiled by Authors

LULC Classes		2022								
		Units	Agriculture	Bare Ground	Built up	Grass Land	Trees	Water Body	Total Ha Opening _ 2017	%
2017	Agriculture	Ha	2746.05	0.00	23.08	363.77	0.70	7.04	3140.63	52
		%	87.00	0.00	1.00	12.00	0.00	0.00		
	Bare Ground	Ha	0.65	6.23	0.00	2.92	0.00	0.00	9.81	0
		%	7.00	63.00	0.00	30.00	0.00	0.00		
	Built up	Ha	163.16	0.66	375.82	69.28	2.56	1.47	612.96	10
		%	27.00	0.00	61.00	11.00	1.00	0.00		
	Flooded Vegetation	Ha	0.00	0.00	0.60	0.00	0.00	0.00	0.60	0
		%								
	Rangeland (Grass/ Grazing Land)	Ha	176.23	0.56	4.62	1820.66	79.31	1.45	2082.84	35
		%	9.00	0.00	0.00	87.00	4.00	0.00		
	Trees (Plantation)	Ha	30.26	0.00	0.22	33.81	16.86	0.46	81.61	1
		%	37.00	0.00	0.00	41.00	21.00	1.00		
	Water Body	Ha	20.70	0.00	0.06	32.42	0.33	65.30	118.81	2
		%	18.00	0.00	0.00	27.00	0.00	55.00		
	Total Ha_ Closing 2022	Ha	3137.06	7.46	404.40	2322.86	99.76	75.72	6047.26	
		%	52.00	0.00	7.00	38.00	2.00	1.00		

5.5.b Transition Matrix of Kothur

Table 13: Transition Matrix of Kothur
Source: Compiled by Authors

LULC Classes		2022								
		Units	Agriculture	Bare Ground	Built up	Range land	Trees	Water Body	Total Opening Extent _2017	%
2017	Agriculture	Ha	3372.61	0.00	159.31	199.25	11.36	78.80	3821.32	89.00
		%	88.00	0.00	4.00	5.00	1.00	2.00		
	Built up	Ha	38.64	0.90	333.69	1.69	0.17	1.56	376.64	9.00
		%	10.00	0.00	89.00	1.00	0.00	0.00		
	Range Land	Ha	66.55	0.00	8.39	35.29	0.77	1.09	112.09	2.00
		%	59.00	0.00	8.00	31.00	1.00	1.00		
	Trees	Ha	1.14	0.00	0.00	0.00	0.17	0.00	1.31	0.00
		%	87.00	0.00	0.00	0.00	13.00	0.00		
	Water Body	Ha	0.00	0.00	0.00	0.00	0.00	1.35	1.35	0.00
		%								
Total Closing Extent_2022		Ha	3478.94	0.90	501.39	236.23	12.47	82.80	4312.72	
		%	81.00	0.00	12	4	1	2		

5.5.c Transition Matrix of Sangareddy

Table 14: Transition Matrix of Sangareddy
Source: Compiled by Authors

LULC Classes		2022									
		Units	Agriculture	Bare Ground	Built up	Flooded Vegetation	Grass Land	Trees	Water Body	Total Opening Extent_ 2017	%
2017	Agriculture		3800.56	1.80	299.06	3.40	34.17	4.15	76.92	4220.05	89
	Bare Ground		0.00	1.64	0.00	0.00	0.00	0.00	0.12	1.76	0
	Built up		25.14	0.00	275.66	0.00	0.00	0.07	0.83	301.69	6
	Grass/Grazing Land		9.65	10.33	8.35	0.00	107.16	0.00	0.00	135.50	3
	Trees		1.11	0.00	0.35	0.00	0.00	5.99	0.00	7.44	0
	Water Body		4.58	0.00	1.30	0.00	0.03	0.00	98.69	104.60	2.00
Total Closing Extent _2022			3841.04	13.78	584.71	3.40	141.36	10.20	176.55	4771.04	
		%	81	0	12	0	3	0	4		

5.5.d Transition Matrix of Tupran

Table 15: Transition Matrix of Tupran
Source: Compiled by Authors

LULC Classes		2022									
		Units	Agriculture	Bare Ground	Builtup	Flooded Vegetation	Grass Land	Trees	Water Body	Total Opening _2017	%
2017	Agriculture	Ha	3986.18	0.00	328.58	2.17	239.67	8.25	112.95	4677.81	76.00
		%	85.00	0.00	7.00	0.00	5.00	0.00	3.00		
	Bare Ground	Ha	0.00	2.91	0.69	0.00	0.05	0.00	0.00	3.65	0.00
		%	0.00	80.00	19.00	0.00	1.00	0.00	0.00		
	Built up	Ha	34.22	0.00	697.55	0.00	1.67	0.00	0.30	733.74	12.00
		%	5.00	0.00	95.00	0.00	0.00	0.00	0.00		
	Flooded Vegetation	Ha	0.00	0.00	0.00	0.23	0.00	0.00	4.16	4.39	0.00
		%	0.00	0.00	0.00	3.00	0.00	47.00	50.00		
	Grass/ Grazing Land	Ha	212.44	0.71	79.63	0.00	357.27	0.06	1.23	651.33	11.00
		%	33.00	0.00	12.00	0.00	55.00	0.00	0.00		
	Trees	Ha	8.18	0.00	1.44	0.00	6.10	0.01	1.17	16.90	0.00
		%	48.00	0.00	9.00	0.00	36.00	0.00	7.00		
	Water Body	Ha	5.85	0.00	0.13	1.16	0.01	0.00	47.23	54.37	1.00
		%	11.00	0.00	0.00	2.00	0.00	0.00	87.00		
Total Closing _2022		Ha	4246.88	3.62	1108.02	3.56	604.77	8.32	167.02	6142.19	
		%	69.00	0.00	18.00	0.00	13.00	0.00	3.00		

It has been observed that four distinct mandals have undergone notable transformations characterised by conversions, with Tupran standing out as the mandal showcasing the most significant occurrences of such changes. The evaluation of accuracy reveals a substantial degree of concordance in the findings; however, it also highlights that Tupran has experienced a higher conversion rate relative to its counterparts within the other mandals. Additionally, the transition matrix provides critical insights into land use shifts, illustrating how agricultural lands have been repurposed into developed areas and barren ground. This shift not only reflects current trends but also suggests considerable possibilities for future construction projects and urban development endeavors in these areas. The implications of these conversions are multifaceted, impacting local economies and environmental dynamics while paving the way for new infrastructures.

6. Conclusions and Recommendations

This study assessed land use changes in peri-urban areas of four mandals in the Hyderabad Metropolitan Region from 2017 to 2022 using multi-temporal satellite imagery. Findings indicate significant loss of agricultural, rangeland and water bodies due to urban expansion. For example, agricultural land in Tupran decreased from 46.79 km² to 42.48 km², while Kothur and Sangareddy also saw declines. Urbanisation has led to ecological disturbances and increased demand for built-up areas driven by population growth and low-density development.

The analysis highlighted that economic growth and demographic trends are key factors behind these transformations, with Hyderabad mainly expanding northward towards industrial areas like Tupran. However, some regions, such as Bibinagar, experienced minimal change, suggesting potential for preserving natural assets.

The comprehensive methodology combining satellite data and geographic information systems aids in identifying urban growth patterns crucial for regional planning and policy-making. Awareness among urban planners, policymakers and the public about sustainable resource management is essential.

These findings underscore the need for carefully crafted land use plans and environmental policies to mitigate negative impacts on agriculture, natural habitats and water resources due to rapid urbanisation.

References

Aldwaik, S. Z., & Pontius, R. G., Jr. (2013). Map errors that could account for deviations from a uniform intensity of land change. International Journal of Geographical Information Science, 27(9), 1717–1739. https://doi.org/10.1080/13658816.2013.787618

Angel, S., Sheppard, S., Civco, D. L., et al. (2005). The dynamics of global urban expansion. Citeseer.

Berling-Wolf, S., & Wu, J. (2004). Modeling urban landscape dynamics: A review. Ecological Research, 19(1), 119–129. https://doi.org/10.1111/j.1440-1703.2003.00610.x

Coppin, P. R., Jonckheere, I., Nackaerts, K., Muys, B., & Lambin, E. (2004). Digital change detection methods in ecosystem monitoring: A review. International Journal of Remote Sensing, 25(9), 1565–1596. https://doi.org/10.1080/014311603100010167

Dadras, M., Shafri, Z. H. M., Ahmad, N., Pradhan, B., & Safarpour, S. (2014). Land use/cover change detection and urban sprawl analysis in Bandar Abbas city, Iran. The Scientific World Journal, 2014, Article 690872. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4167654/

European Environment Agency (EEA) & FOEN. (2016). Urban sprawl in Europe (EEA Report No. 11/2016). https://www.eea.europa.eu/publications/urban-sprawl-in-europe

Fenta, M. M., Yasuda, H., Shimizu, K., Haregeweyn, N., & Mekonnen, D. F. (2017). The dynamics of urban expansion and land use/land cover changes using remote sensing and GIS: A case study of Bahir Dar City, Ethiopia. International Journal of Remote Sensing, 38(14), 4107–4129. https://doi.org/10.1080/01431161.2017.1317936

Goswami, M. (2018). Conceptualising peri-urban-rural landscape change for sustainable management (Working Paper No. 425). Institute for Social and Economic Change. http://www.isec.ac.in/WP%20425%20

Hu, Y., Kong, X., Zheng, J., Sun, J., Wang, L., & Min, M. (2018). Urban expansion and farmland loss in Beijing during 1980–2015. Sustainability, 10(11), 3927. https://doi.org/10.3390/su10113927

Jensen, J. R. (2005). Introductory digital image processing: A remote sensing perspective (3rd ed.). Pearson Prentice Hall.

Jiang, L., Deng, X., & Seto, K. (2013). The impact of urban expansion on agricultural land use intensity in China. Land Use Policy, 35, 33–39. https://doi.org/10.1016/j.landusepol.2013.04.011

Krishnaveni, K. S., & Anilkumar, P. P. (2020). Managing urban sprawl using remote sensing and GIS. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-3/W11, 59–66. https://doi.org/10.5194/isprs-archives-XLII-3-W11-59-2020

Lutzenberger, A., Brillinger, M., & Pott, S. (2014). Global land-use analysis (UFOPLAN Research Report 3711 93 101). Leuphana Universität Lüneburg, Institute for Sustainable and Environmental Chemistry. https://www.ecologic.eu/sites/default/files/project/2021/Land%20Use%20Analysis%20final%20en.pdf

Maktav, D., Erbek, F. S., & Jürgens, C. (2005). Remote sensing of urban areas. International Journal of Remote Sensing, 26(4), 655–659. https://doi.org/10.1080/01431160512331316469

Meng, Y., Wang, M., Xu, W., Guan, X., & Yan, D. (2022). Structure construction, evolution analysis and sustainability evaluation of Water-Ecological-Economic system. Sustainable Cities and Society, 83, Article 103966. https://doi.org/10.1016/j.scs.2022.103966

Mohan, M., Pathan, S. K., Narendrareddy, K., et al. (2011). Dynamics of urbanisation and its impact on land-use/land-cover: A case study of megacity Delhi. Journal of Environmental Protection, 2(9), 1274–1283. https://doi.org/10.4236/jep.2011.29146

Ramachandra, T. V., & Kumar, U. (2004, September). Geographic Resources Decision Support System for land use, land cover dynamics analysis. Proceedings of the FOSS/GRASS Users Conference, Bangkok, Thailand, 12–14 September 2004. Centre for Ecological Sciences, Indian Institute of Science. http://ces.iisc.ernet.in/energy/Welcome.html

Ramachandra, T. V., Aithal, B. H., & Sanna, D. D. (2012, February). Landscape dynamics through spatial metrics. Conference Paper. https://www.researchgate.net/publication/271199576

Sun, C., Wu, Z. F., Lv, Z. Q., et al. (2013). Quantifying different types of urban growth and the change dynamic in Guangzhou using multi-temporal remote sensing data.

International Journal of Applied Earth Observation and Geoinformation, 21, 409–417. https://doi.org/10.1016/j.jag.2012.06.005

Tabuchi, T. (2013). Agglomeration in world cities. Procedia - Social and Behavioral Sciences, 77, 299–307. https://doi.org/10.1016/j.sbspro.2013.03.086

Teferi, E., Bewket, W., Uhlenbrook, S., & Wenninger, J. (2013). Understanding recent land use and land cover dynamics in the source region of the Upper Blue Nile, Ethiopia: Spatially explicit statistical modeling of systematic transitions. Agriculture, Ecosystems & Environment, 165, 98–117. https://doi.org/10.1016/j.agee.2012.11.007

Zhong, S., Wang, M., Zhu, Y., Chen, Z., & Huang, X. (2022). Urban expansion and the urban–rural income gap: Empirical evidence from China. Cities, 129, Article 103831. https://doi.org/10.1016/j.cities.2022.103831

Ar. Sridevi. T holds the position of Research Scholar in the Department of Architecture and Urban Planning at Jawaharlal Nehru Architecture and Fine Arts University, Hyderabad, India. She has accumulated 15 years of experience in various architectural and urban planning capacities, including a diverse array of professional and academic projects.
Email: srideviarch@gmail.com

Dr. S. Kumar is a Professor of Architecture at JNAFAU. A graduate of JNTU with postgraduation from CEPT and a Ph.D. from JNAFAU, he specialises in housing, planning and traditional architecture. He has held key academic leadership roles and actively contributes to sustainable design education, research, and institutional development.
Email: skumar@jnafau.ac.in

Ar. B. Sai Akhila is an Assistant Professor at ICFAI School of Architecture, IFHE. She teaches architectural design, urban design and heritage conservation. Her research focuses on heritage management and historical cities. A postgraduate from SPA Vijayawada, she has presented widely on urbanisation and heritage, with five key publications in 2024.
Email: saiakhilab1996@gmail.com

RESEARCH PAPER

This research paper was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, 29-31 August 2024, under Stream 2 - The Significant Present

Strategic Redevelopment Plan for the Brahmapuram Waste Treatment Plant at Kakkanad.

By Ar. Maria Paul, Ar. Arun Balan and Ar. Priya Pradeep

ABSTRACT:
Deeply ingrained strategies for active municipal waste management are necessary in light of the growing challenges of urbanisation and environmental sustainability. In the context of Kerala, waste management is a topic that is often debated. However, barely any milestone strategy has been developed regarding the meticulous control of the flow of incoming rubbish at the different processing plants. Debates on rubbish reduction, collection and segregation have overshadowed the importance of efficient waste processing. Globally, numerous parcels of land have unintentionally become massive landfills, leading to ecological imbalances. A similar fate could await the Brahmapuram waste treatment plant at Kakkanad if it is not addressed urgently. In this study, the current state of the Brahmapuram waste treatment plant is examined by identifying its shortcomings and potential for redevelopment. The project aims to shift from traditional waste management approaches to a comprehensive sustainable waste-to-resource strategy focused on recovering compost from waste through design-based research. The methodology thoroughly analyses the existing infrastructure, operational inefficiencies and potential for integrating advanced waste processing technologies. Key findings highlight the urgent need for a comprehensive master plan strategically designed to handle and manage 500 tonnes per day (TPD) of waste. This plan includes innovative strategies for waste segregation, processing and resource recovery, ensuring a sustainable and environmentally friendly waste management system for the region.

KEYWORDS: environmental sustainability, municipal waste management, compost, landfills

1. INTRODUCTION

Human activity produces waste, resulting in environmental pollution and health issues for the public. The increase in the quantity and complexity of these wastes is due to increased economic development, urbanisation and improved living standards (Gupta, 2015). Strategies for waste collection, segregation and reduction are a heated topic of discussion in various research papers. All these discussions overshadow the demand for appropriate site-specific workflow management of waste within a processing site (Gupta, 2015; Rasmeet, 2021; Dev & Siddharth, 2020; Nanda, Sonil & Franco, 2021). Many parcels of land once intended to manage municipal solid waste have now become landfills (Simis, Awang & Arifin, 2016; Thani, Rahim & Mohamad, 2016). Several anthropogenic and non-anthropogenic factors are responsible for the same.

A similar fate befell the Vilappilsala site at Trivandrum, Kerala, which was forced to shut down due to protests from the neighbourhood. The improper management of incoming waste resulted in various social and environmental hazards to the surrounding area. In Kochi, a centralised waste management system is adopted at the Brahmapuram waste treatment plant, Kakkanad. Recently, various media reported a massive fire outbreak in March 2023 at the plant, which resulted in major parts of the city being blanketed in hazardous smoke. It is high time to discuss the systematic management flow of incoming waste.

It would be challenging for the authorities to identify a similar open land, easily accessible from the urban context but distant from public life, as the Brahmapuram site, for managing day-to-day municipal solid waste. Redeveloping the current waste land can thus be concluded to be a more sustainable and viable option.

1.1 Aim and Objectives

Based on the Census of India 2011, using the geometric mean method, the projected population of the Kochi Municipal Corporation(KMC) by 2045 is expected to be 8 lakhs. Accordingly, the expected waste generation will be 500 tonnes per day (TPD) (Swachh Bharat Manual Part 2). Against this background, the paper aims to propose a redevelopment plan for the Brahmapuram waste treatment plant with a daily intake of 500 TPD of biodegradable waste. To meet this aim, the paper is structured into three parts, with the study of the current state of the plant as the initial focus. Based on this, the most viable sustainable biodegradable waste management strategy is adopted. By adhering to the existing rules and byelaws, a master plan is proposed for the current site to accommodate the daily inflow of 500 TPD of biodegradable waste.

1.2 Scope and Limitations

The study aims to develop a waste management site prototype with a systematic flow of waste that can be adopted in similar conditions hereafter. The formation of legacy waste is to be nil from this point forward. The project also emphasises how to regain the social, environmental and economic values of the site and its neighbourhood. For the completion of the project, the site is expected to receive only biodegradable waste from the Kochi Municipal Corporation hereafter.

2. LITERATURE REVIEW

2.1 Waste

Waste refers to material or materials that are no longer useful or necessary and are typically discarded. Figure 1 shows the different types of waste. Municipal Solid Waste (MSW), commonly referred to as garbage, consists of everyday items that we use and then discard. Figure 2 shows the different types of MSW. Figure 3 illustrates the rising trend in the amount of MSW generated. Figure 4 shows the global MSW management strategies. The Government of Kerala has adopted a policy for solid waste management with two strategies: Decentralized waste management and Centralized waste management

Figure 1: Types of wastes
Noor, 2020

Figure 2 Types of MSW
Noor, 2020

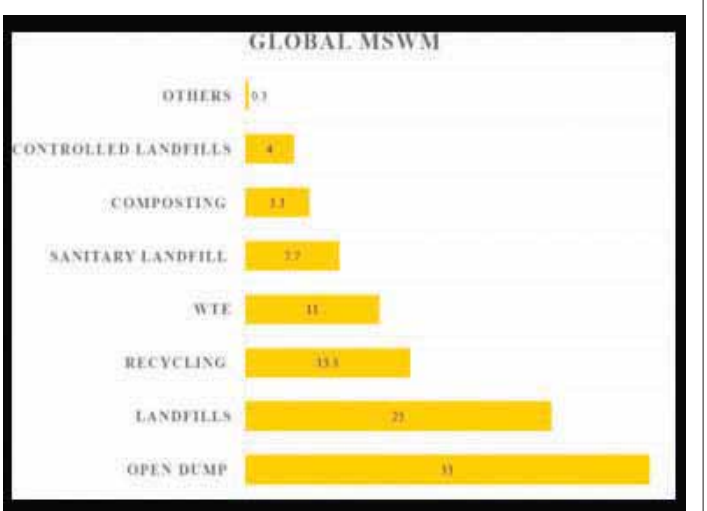


Figure 3 Global MSWM. Redrawn by the author
Sharma & Jain, 2018

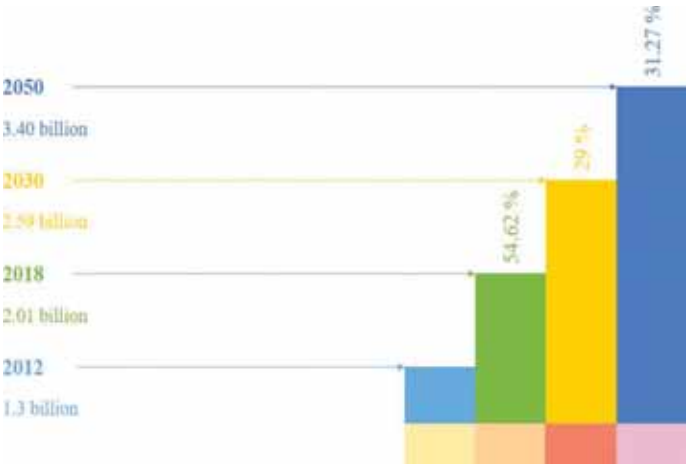


Figure 4 Rising amount of MSW
The World Bank report, 2018

2.2 MSW management

Broadly, Municipal Solid Waste Management (MSWM) can be classified into biological and thermal treatments. The former involves the use of bacteria to break down organic particles, while the latter involves the application of heat to reduce the volume of waste, thereby recovering energy from the matter (Sharma & Jain, 2018).

2.3 Impacts of landfills

Figure 5 illustrates the various impacts of a landfill on both the environment and human health. Landfills emit greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2), which contribute to global warming and climate change. These emissions can have severe consequences for human health, leading to respiratory issues and other chronic diseases. Additionally, the risk of landfill collapse poses a significant threat to nearby communities, potentially causing extensive damage and loss of life. Landfills are also prone to fires, which can release harmful pollutants into the air and further exacerbate health problems for residents. These factors highlight the urgent need for effective waste management practices to mitigate the adverse effects of landfills.

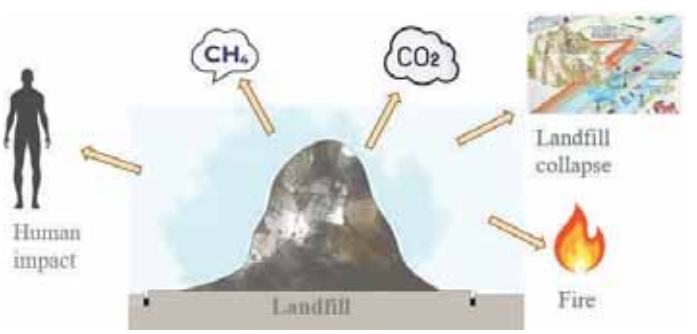


Figure 5 Impacts of landfill
Source: Authors

2.4 Methane emission from landfill site and its relation with climate change

The decomposition of organic matter results in landfill gas (LFG). Currently, landfills account for 14% of global methane emissions—a figure expected to rise to around 70% by 2050, according to the World Bank. Methane is responsible for approximately 30% of the current rise in global temperature and has more than 80 times the warming power of carbon dioxide over the first 20 years after it reaches the atmosphere. In India, the waste sector contributes about 20% of methane emissions, as reported by the Global Methane Tracker 2022.

3. METHODOLOGY

Figure 6 shows the methodology chart followed for the study. The entire project was designed as a quantitative research study. The initial objective—to examine the current scenario of the plant—was addressed through on-site data collection, forming the primary dataset. The type and quantity of waste and the operational flow of the plant were studied and analysed through several site visits and interviews with on-site authorities. This data was then cross-checked with records available from the Kochi Municipal Corporation. It formed the basis for the next stage of the project: investigating the most viable and sustainable management strategy to be implemented at the study site. Several research papers supported this investigation. Based on these findings, a workable management flow of waste was developed and subsequently translated into a master plan for the entire 110-acre land parcel.

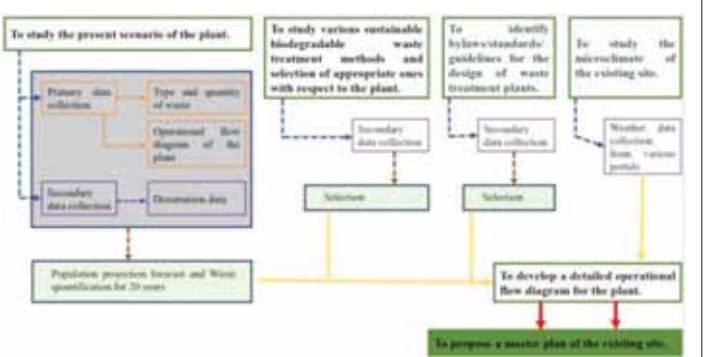


Figure 6 Methodology chart
Source: Authors

4. DATA ANALYSIS AND FINDINGS

4.1 Site

Brahmapuram is located in the southwest of Ernakulam district, Kerala. The geographical coordinates are 9.993641° N latitude, 76.363217° E longitude, and the site lies 23 metres above mean sea level. Figures 7 and 8 show the existing site plan and the operational flow of the Brahmapuram plant respectively. Table 1 illustrates the type, quantity

and number of loads of waste reaching the plant from the Kochi Municipal Corporation. Figure 9 and 10 illustrates a schematic zoning layout of the plant. Tables 1 and 2 represent the type and quantity of wats reaching the site before and after March 2023.

Figure 7 The existing site plan
Source: Authors

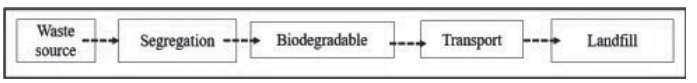


Figure 8 The operational flow of the plant
Source: Authors

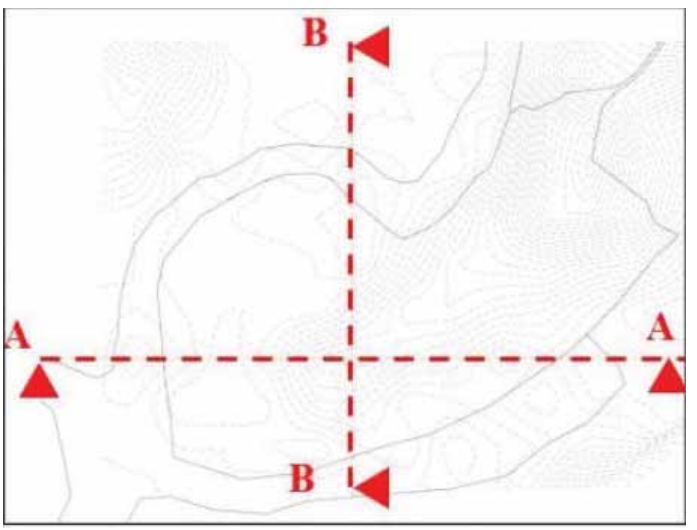


Figure 9 Key plan
Source: Authors

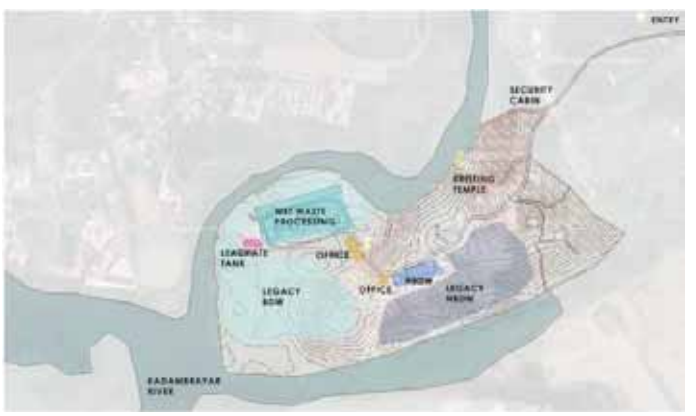


Figure 10 The existing zoning layout of the plant
Source: Authors

Table 1: The type and quantity of waste before March 2023
Source: Authors

ULB	No of loads	Types of waste	Quantity of waste (TPD)
Cochin corporation	23	Bio and non- bio degradable	240

Table 2: Quantity of waste after March 2023
Source: Authors

Types of waste	Quantity of waste (TPD)
Biodegradable	200

4.2 Topography of the site

The site has an undulating terrain with slopes running from east to west. During the monsoon, the water level rises to approximately 1.0 metre above ground in the area adjoining the Kadambrayar river. Figure 11 shows the contour analysis carried out using GIS. Figures 12 and 13 illustrate schematic site sections AA and BB. The sections show that the site's drainage flows towards the west side—Kadambrayar River. This would direct leachate and stormwater runoff into the river. From this, it is concluded that the existing terrain of the site needs to be altered in accordance with the proposed amenities.

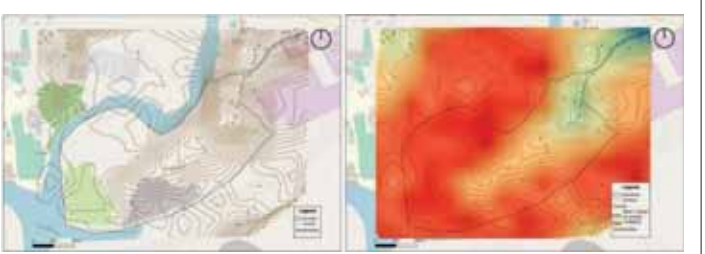


Figure 11 Generated site contours
Source: Authors

Figure 12 Site section AA
Source: Authors

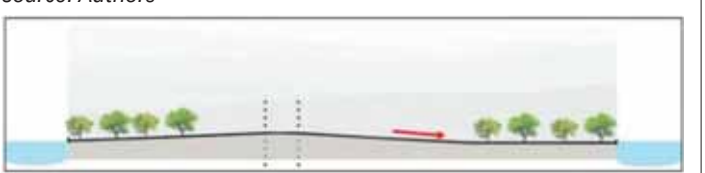


Figure 13 Site section BB
Source: Authors

4.3 Existing site infrastructure

The site consists of a security cabin, a non-functioning weighbridge, a record room, portable sanitation blocks and houses of displaced people.

4.4 Kadambrayar river

The Kadambrayar River is a major urban water body (10°10'46.92"N, 76°22'52.32"E) that originates in the eastern part of Ernakulam district, Kerala, located in the southern part of India, and extends approximately 27 km downstream. The river has a catchment area of about 115 km², and a major stretch of it passes through the rapidly urbanising and industrialised region of Ernakulam. Figure 14 illustrates the drainage pattern of the river.

Figure 14 The drainage pattern of the Kadambrayar river
Source: Authors

4.5 Water table depth

The water table at the site is at a depth of 1.25 metres, as observed in an existing well on the premises. Figure 15 shows the water table in relation to the existing well within the site.

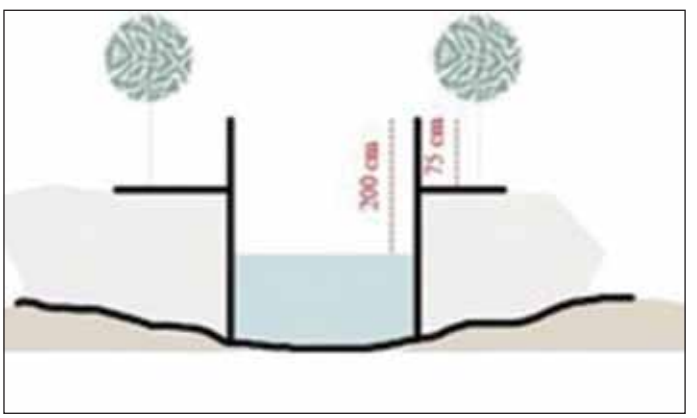


Figure 15 Water table depth
Source: Authors

4.6 Soil

The soil adjoining the river area consists of soft clay with low N values, indicating poor bearing capacity. However, the soil in the upper stretches is fairly suitable for construction. Figure 16 illustrates the ecological study of the context, while Figure 17 shows various images of the site from the marked points.

5. RESULTS AND DISCUSSION

The preparation and implementation of a detailed, scientific management plan for the site can significantly reduce its socio-economic and environmental impacts. By adopting a multidisciplinary approach

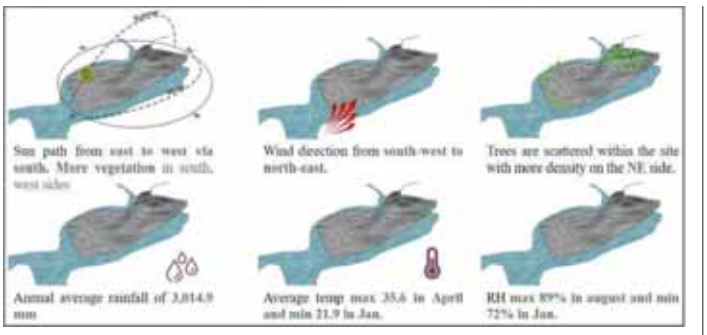


Figure 16 Ecological context analysis
Source: Authors

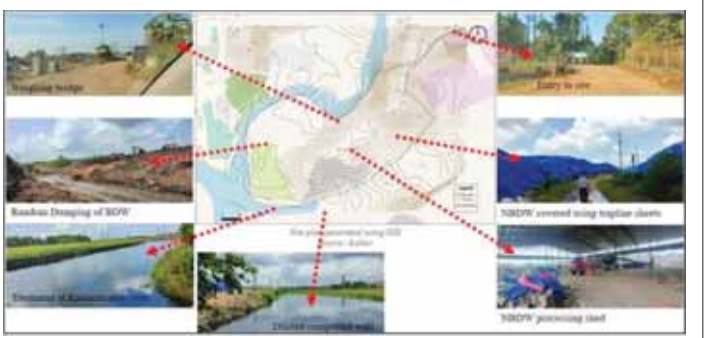


Figure 17 Photographs of the site
Source: Authors

to planning and implementation—which includes architects, engineers, environmentalists, social workers, the public and other stakeholders—many issues can be effectively addressed from the discussion stage itself. The adoption of suitable waste processing facilities and the use of efficient technologies can further mitigate the adverse impacts of the plant. Currently, pollution from the plant is affecting the health of nearby residents and workers, leading to cardiovascular diseases, cancer and other skin problems. Additionally, poor management practices are causing a decline in property values, and local settlements within a 5 km radius have relocated. The dumping of untreated waste also attracts scavenger birds, posing a threat to nearby residential areas.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

While discussions on waste reduction, collection and segregation have gained attention, the nuanced management flow of incoming waste at processing sites has been largely overshadowed. Through rigorous research, a comprehensive master plan for the site was strategically designed to handle and manage a staggering 500 tonnes per day (TPD) of waste. The outcomes of this thesis project represent a pivotal step towards realising the overarching goal of a more sustainable future for the Brahmapuram waste treatment plant. It is hoped and anticipated that the recommendations arising from this

research—grounded in comprehensive analysis and study—will catalyse further exploration and practical initiatives in the domain of waste management and regeneration.

6.2 Recommendations

- Waste reduction strategies should be implemented to lessen the burden at the plant source.
- The plant's daily operations must be regulated through a systematic management plan.
- Workers should be made aware of the importance of a structured management flow within the process.
- To ensure smooth functioning, regular meetings involving workers, office personnel, KMC authorities and associates should be conducted.
- Environmental impact analysis should include the installation of air quality monitoring equipment and periodic water quality testing within a defined radius.
- Research into technological innovations in environmentally friendly waste processing and their potential integration on-site should be pursued.
- On-site energy generation should be utilised to reduce dependency on external sources.

The overall master plan of the site will undergo a noticeable transformation once the aforementioned recommendations are implemented. Initially, a significant amount of legacy waste is visible throughout the area. However, with the adoption of the proposed measures, a well-structured and organised site will emerge. To effectively delay the onset of air and water pollution from the site, a 10-metre green belt along with an additional 10-metre buffer zone will be developed around its perimeter. The proposed redevelopment will be executed gradually in phased stages. A critical deficiency has been addressed by successfully establishing an organised workflow for the entire site. Greater emphasis is now placed on sustainable practices such as recycling water and utilising energy generated on-site.

6.2.1 Human Health Benefits

- Improve psychological well-being of individuals within the site and surrounding neighbourhoods
- Reduce the spread of pathogens
- Enable the use of Kadambrayar River water for secondary purposes through basic treatment measures

6.2.2 Environmental Benefits

- Reduce methane emissions and mitigate climate change, thereby lowering the frequency of fire outbreaks
- Reduce air pollution
- Reduce water pollution in the Kadambrayar River
- Enhance aquatic life

6.2.3 Economic Benefits

- Decrease resource consumption
- Promote on-site energy utilisation

6.2.4 Social Benefits

- Increase the real estate value of nearby properties
- Improve the overall quality of life

Figure 18 illustrates the proposed operational flow of the plant. Based on this, the master plan has been developed. The existing and proposed site layouts are illustrated in Figure 19. The benefits of the proposed plan are presented in Table 3.

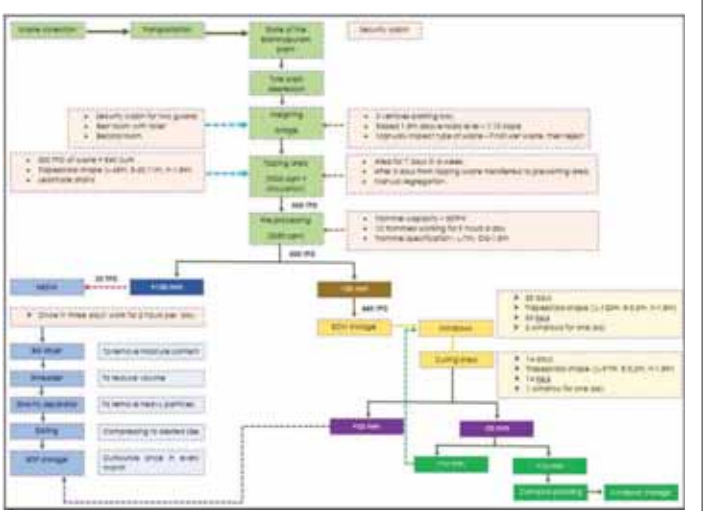


Figure 18 Proposed operation flow for the plant
Source: Authors

Figure 19 Existing v/s Proposed site plan
Source: Authors

Table 3 Benefits of the proposed master plan
Source: Authors

Human health benefits	• Improve psychological benefits of people within the site, neighbourhoods etc. • Reduce the spread of pathogens • The Kadambrayar River water can be used for secondary purposes with some basic treatment measures.
Environmental benefits	• Reduce methane emissions and thus climate change – reduce the frequency of fire outbreaks • Reduce air pollution • Reduce water pollution of Kadambrayar river • Improve aquatic life
Economic benefits	• Reduce resource consumption • Onsite energy utilization
Social benefits	• The real estate value of nearby property will rise. • Improved quality of life

REFERENCE

Dev, S., & Siddharth, J. (2020). Municipal solid waste generation, composition, and management: The global scenario.

Government of India. (2021, June). Three key forms of temple architecture. Azadi Ka Amrit Mahotsav. Retrieved 2024, from https://amritmahotsav.nic.in/blogdetail.htm?70

Gupta, N. K. (2015). A review on current status of municipal solid waste management in India.

Joshi, A., & Bhise, A. (2006). Role of urban fringe in metropolitan development. Journal of the Indian Institute of Architects (JIIA), 3(10), 12–16.

Nanda, B., Sonil, & Franco. (2021). Municipal solid waste management and landfilling technologies: A review.

Noor, T. J. (2020). Types, sources and management of urban wastes. In Urban Ecology: Emerging Patterns and Social-Ecological Systems. https://doi.org/10.1016/B978-0-12-820730-7.00014-8

Rasmeet, S. (2021). Municipal solid waste management in the city of Indore: A case study.

Sharma, K. D., & Jain, S. (2018). Overview of municipal solid waste generation, composition, and management in India. Journal of Environmental Engineering. https://doi.org/10.1061/(ASCE)EE.1943-7870.0001490

Shinde, K. (2014). Ganesh Festival: A ten-day extravaganza. In J. Laing & W. Frost (Eds.), Rituals and traditional events in the modern world (pp. 24–38). London: Routledge.

Simis, M., Awang, A., & Arifin, K. (2016). From ex-landfill to public park: Impact on local community's quality of life and living environment.

Thani, S. K., Rahim, N. A., & Mohamad, N. H. (2016). Grey to green: Rehabilitation of urban dump site.

Ar. Maria Paul is an Assistant Professor at SCMS School of Architecture, Karukutty. She holds a Master's degree in Sustainable Architecture from MES School of Architecture, Kuttippuram (2023). With over 3.5 years of professional experience under eminent architects in Kochi, her research focuses on sustainable urban development, decentralised waste management systems, and participatory planning, with a specific interest in context-sensitive redevelopment strategies in urban Kerala.
Email: ar.mariapaul94@gmail.com

Ar. Arun Balan U is an Associate Professor at MES College of Engineering, Kuttippuram. With over 25 years of professional experience and 17 years of academic experience, his research interests include environmental architecture, sustainable design practices and heritage conservation. His work spans ecotourism planning, green building strategies and sustainability in hospitality and urban redevelopment contexts.
Email: arunuab2021@gmail.com

Ar. Priya Pradeep is an Associate Professor at Marian College of Architecture and Planning, with over twelve years of teaching experience and two years in professional practice under eminent architects in Kollam. A practising consulting architect since 2011, her research interests include climate-responsive architecture, passive solar design, sustainable tourism and integrated water and waste management systems. She has contributed to projects such as the Sustainable Village Tourism Plan for Sindhudurg.
Email: ar.priya1987@gmail.com

RESEARCH PAPER

Intellectual Property Rights in Architectural Practice and Academics
Paradoxes and Prospects

By Dr. Vasudha Gokhale

ABSTRACT:
Architectural work originates in the designer's mind, combining art, environmental design science and technology to manifest an idea in real life. These creative endeavours are vulnerable to unauthorised use by others, affecting the creator either economically or morally. Intellectual property concerns have become more pronounced in the context of knowledge misappropriation, erosion of the public domain and increasing anticompetitive academic practices. However, professionals, academicians and students engaged in knowledge production often lack awareness regarding intellectual property rights (IPR) issues in the architectural discipline. This paper provides a detailed account of the nuances of IPR in architectural practice and academia. Various legal provisions instrumental in protecting architectural production and education are discussed. The determinants of architects' behaviour in opting for IP protection are examined through a questionnaire survey informed by the Theory of Reasoned Action and Protection Motivation Theory. A low level of IPR awareness was identified as exerting a considerable negative influence on Indian architectural professionals' and academicians' attitudes towards and use of IPR. It is argued that knowledge of IP issues helps mitigate risks and avoid costly disputes and distress, thereby better protecting their interests.

KEYWORDS: Panorama, Plagiarism, Copyright, Infringement, Penalty

1. INTRODUCTION

Intellectual Property Rights (IPR) refer to the rights providing legal protection to contributions and inventions across all human creative endeavours, including artistic, literary, broadcast, performance, photographic, scientific and architectural works. IPR safeguards against unfair competition and prevents others from copying or engaging in actions without the copyright owner's consent (Nemlioglu, 2019).

Architectural works are recognised as edifices that express the designer's cultural values and ideologies within the specific cultural context in which they originated. The provision of intellectual property and cultural property rights is crucial in architecture. It must be acknowledged that architectural creations and knowledge production may belong to a particular nation, state, ethnic community or individual (Özeren, Qurraie & Eraslan, 2024).

Architects create structures and spaces with considerable effort and skills acquired over many years, demonstrating their talent, creativity and ingenuity. These creations are vulnerable to misuse in various ways, including copying, derivation, modification and redistribution without consent. In today's digital world, such replication can be done quickly and accurately. Acknowledging this risk, the American Institute of Architects (AIA) urges architectural professionals to diligently protect their work.

Various types of intellectual property relevant to architecture include trademarks, copyrights, industrial design patents and trade secrets

(MacMurray, 2004). In India, the Copyright Act of 2012, the Design Act of 2000 and the Trademark Act of 1999 offer legal protection for architectural creations. However, there is a concerning lack of awareness and understanding about IPR among professionals prior to designing and constructing buildings, which introduces potential financial risk and legal liability.

Knowledge is a critical source of innovation, and while knowledge sharing and exchange are essential, they are also accompanied by the risk of misuse (Olaisen & Revang, 2017). The World Intellectual Property Organization (WIPO) addresses IP issues globally, enabling designers, innovators, creators and entrepreneurs to promote and protect their intellectual property. India is a member of WIPO, which currently has 192 member states.

The International Association for the Advancement of Teaching and Research in Intellectual Property (ATRIP), established by WIPO in 1981, acts as a nodal agency for education, training and research in IPR. In India, the Ministry of Electronics and Information Technology (MeitY) has taken significant steps to foster a supportive ecosystem for the creation, protection, awareness and commercialisation of intellectual property and IPR (Ahmed & Varun, 2017).

Educational programmes focusing on IPR have been shown to significantly improve knowledge and perceptions of IPR, influencing students' participation in entrepreneurial activities (Devasena, 2024). As IPR is increasingly recognised as an economic driver, the education system must proactively address its awareness and understanding. While architectural students are typically familiar with the basic concepts of IPR, they often lack deeper knowledge regarding its legal protection.

Due to this limited understanding, many researchers fall victim to plagiarism. This paper aims to provide architectural professionals and students with a clear understanding of IPR and related legal issues, helping them safeguard their creative work from misuse. It also supports students in maintaining control over their academic output and intellectual contributions, thereby enhancing learning, innovation and awareness, with a particular focus on trademarks and copyrights.

2. HISTORIC BACKGROUND

Patent rights can be traced back to the Greek era in 500 BCE, where individuals who discovered new products were encouraged to promote luxury in the city of Sybaris. Patents were systematically granted in Venice from 1450, with a decree providing legal protection against infringement for new and inventive devices for a period of ten years. The 1421 Florentine Patent Statute and the Venetian Statute of 1474 represent the earliest codified laws protecting intellectual property (Bently, 2017). These statutes recognised the rights of authors, inventors and artists over their intellectual works, a principle that would later form a key component of common law in England and the United States (May, 2002).

Interestingly, the architect and engineer Filippo Brunelleschi was the first recorded recipient of a patent for an industrial invention, granted by the Republic of Florence. The identification of personal property dates back thousands of years—Stone Age cave paintings already displayed early marks used for livestock branding. In ancient Egypt, quarry marks, stonecutter signs, references to the stone's origin and the names of labourers were inscribed on masonry works. In the United States, the Freemasons' secret society preserved trade secrets as confidential information shared only within a business or select group to maintain a competitive advantage.

In India, George A. De Penning, an inventor and civil engineer from Kolkata, received a patent in 1856 for his invention titled "An Efficient Punkah Pulling Machine" (Booth, 2015; Rout, 2018). Earlier, the East India Company enacted a copyright law in 1847 that granted protection for the owner's lifetime plus seven years post-mortem, with a maximum duration of forty-two years (Bently, 2017).

Trademarking of architectural structures began in the USA, where the Empire State Building's trademark successfully prevented a beer manufacturer from using its image. Several other architectural landmarks in New York acquired copyright protection for their unique features, such as the art deco spire of the Chrysler Building and the neoclassical façade of the New York Stock Exchange (Spence, 2000). Gustave Eiffel patented the structural system of the Statue of Liberty in 1879. William Strauss recognised that monumental structures, due to their unique aesthetic form, should qualify for legal protection (Vacca, 2005). The US Copyright Act protects such structures as sculptures. This includes monuments such as the Statue of Liberty, the Washington Memorial and Grant's Tomb (Figure 1).

Unique features of buildings can also be trademarked—for example, the Eiffel Tower's light design holds copyright. In India, the Indian Hotels Company Limited (IHCL) obtained the country's first architectural IPR protection for the iconic design of the Taj Mahal Palace Hotel, particularly its red-tiled Florentine Gothic dome and grand exterior (Figure 2).

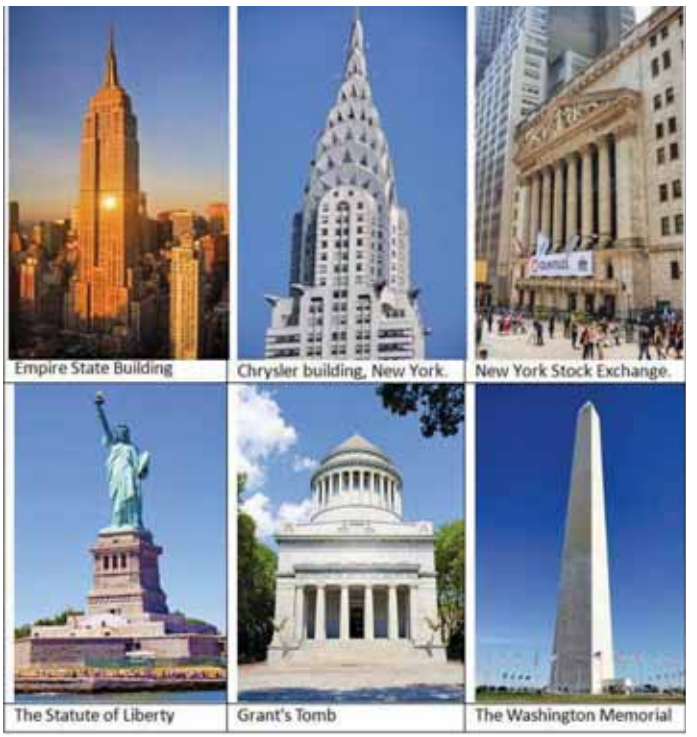


Figure 1: IP protected Buildings and Monuments, USA
Source: Author

Figure 2: Taj Mahal Palace Hotel, Mumbai. - Vasudha Gokhale
Source: https://www.thoughtco.com/taj-mahal-palace-hotel-mumbai-india

Interior layouts may also qualify for trademark protection if they are distinct and represented clearly on paper. A notable case is that of Apple Stores, which hold copyright for their unique layout. In India, trademarking of store layouts is a recent development. Godrej & Boyce M.C. Ltd. pioneered this practice by trademarking their specialised and distinctive retail layout. Well-known buildings and structures with IP protection are presented in Figure 3.

3. PHILOSOPHICAL AND THEORETICAL PERSPECTIVE ON IPR

Historically, patents emerged before copyrights; however, the concept of intellectual property (IP), representing intangible property and individual

Figure 3: Architectural marvels with IPR protection
Source: Author

authorship, appeared prior to both (Hughes, 2011). The Roman architect and military engineer Vitruvius held a stance of veneration—he duly credited past creators and inventors, showing respect for their contributions and authorship.

Theoretically, philosophical perspectives on copyright can be approached through three main frameworks: appropriation, economic and utilitarian theories. According to appropriation theory, the person who first discovers or creates something is legally considered its owner. The creator's contribution grants them an absolute right of ownership and legal protection for the work produced. John Locke's labour theory asserts that a creator has a fundamental right to the product or invention because they have invested energy and effort in creating it (Mossoff, 2012).

Hegelian philosophy, which emphasises the intrinsic relationship between the recognition of the creator and their work, forms the legal foundation for moral rights in copyright (Schroeder, 2005). Economic theory supports the encouragement of creative work through financial incentives. The utilitarian theory, conceptualised by philosopher Jeremy Bentham, maintains that copyright should consider not only the creator but also the users, and public access to copyrighted works is encouraged for broader creative engagement (Ruhtiani, Prihatinah, Sulistyandari, Park & Whindari, 2024).

Protection Motivation Theory posits that individuals protect themselves based on two factors: threat appraisal and coping appraisal. Threat appraisal refers to the perceived probability and severity of a threatening event, while coping appraisal refers to the individual's belief in their ability to act effectively to remove or mitigate the threat (Lee, 2011).

3.1 The Freedom of Panorama

Freedom of expression is a desirable principle, allowing tourists, architects and artists to document architectural masterpieces, public spaces and street art to create memories and share them with others. Freedom of Panorama (FoP) provides this right. The term, derived from the German word Panoramafreiheit, grants individuals the right to take and publish photographs of buildings and structures located in public places, in the public interest.

Article 5 of the Berne Convention (1886) established the "principle of assimilation", which implies that member states of the convention enjoy the right to freedom of panorama. However, this provision is interpreted and applied differently across countries, as shown in Figure 4 (De Rosnay & Langlais, 2017). In India, the provision of FoP is recognised under Section 52 of the Indian Copyright Act of 1957.

Figure 4:Freedom of Panorama Worldwide
Source: Wikimedia Commons

Architects often face IPR infringement due to factors such as ignorance and inadequate legal provisions. A striking example is the case of the Sydney Opera House, where Danish architect Jørn Utzon was unable to contest alterations made to his original design due to the absence of moral rights for architectural works in Australia at the time. The Australian government later addressed this issue with the Copyright Amendment (Moral Rights) Act in 2000. Notably, the Sydney Opera House was only officially trademarked more than 40 years after it was opened (Pappalardo & Meese, 2019).

4. IPR ISSUES WITH THE DESIGN CONCEPT'S ORIGINALITY

Copyright law protects the expression of an idea in tangible form, not the idea itself. In many instances, if an idea is not expressed in a concrete or tangible manner, it may be used by another designer without constituting infringement. A notable example of this principle is the renovation project of New York Hospital, Manhattan, where architect P.C. Attia sued Taylor Clark Architects, Inc. for misappropriating his drawings and falsely designating them as the basis for their renovation design, thereby allegedly violating the Copyright Act.

However, the court ruled that Attia's drawings were only at the conceptual stage—an initial step toward realising a design plan—and represented a rough design idea. In contrast, the defendant, Taylor Clark Architects, had prepared detailed technical drawings for the restructuring of the existing buildings.

Originality of design is a key factor governing intellectual property rights (IPR) in architecture. Architectural design is often influenced by common forms or inspired by historic styles such as Greek and Roman classical architecture or colonial façades. One of the most high-profile cases in architectural IPR involved a postgraduate student at the Yale School of Architecture, who filed a lawsuit against David Childs of the firm Skidmore, Owings & Merrill, alleging that he had copied her Olympic Tower design, which she had presented in a jury where Childs was a panel member.

The central issue in the case was the establishment of originality and the presence of evidence of copying. Shine claimed that Childs' design bore substantial similarity in shape, form, structural grid and façade treatment to her own. However, Childs argued that Shine's design relied on basic and standard forms, and that protecting such elements would be equivalent to protecting general geometric shapes such as ellipses or pyramids. Ultimately, Shine was unable to provide substantial evidence of originality in her composition of design elements, nor was there proof of actual copying (Moon, 2007).

5. ESTABLISHING SUBSTANTIAL SIMILARITY

Another designer may often alter a building's configuration, which can give rise to an intellectual property rights (IPR) issue. In such cases, determining whether substantial similarity exists is critical to establishing a copyright infringement claim. The distinction between an idea and its expression is particularly significant in architectural design.

A Miami-based architectural firm designed an apartment building with a flower-shaped plan and later sued another firm that had taken over the project. The new firm modified the plan by shifting the central bulge of each successive floor's balcony, creating a dynamic, wave-like appearance across the façade. The original design, by contrast, was static (Figure 5).

The court ruled that although the flower-shaped plans appeared superficially similar, the expression of the idea was fundamentally different. Despite

Figure 5: IPR issue for changing architectural configuration
Source: https://www.jdsupra.com/legalnews

comparable exterior forms and conceptual likenesses, the plaintiff's and defendant's designs were not deemed substantially similar (Adibfar, Costin & Issa, 2020).

6. THE RIGHT TO INTEGRITY

An architect's interests often conflict with a building owner's right to modify, restore or demolish a structure to enhance its economic value or improve its appearance. In such situations, the right to integrity protects against unauthorised material alterations. Architects possess moral rights to safeguard their creations from undesirable changes that could damage their reputation, as illustrated by the case of Berlin Central Station, designed by Meinhard von Gerkan in 2006.

This 320-metre-long structure of glass, steel and concrete, with a cathedral-like vaulted ceiling, was designed to stand on the bank of the Spree River. However, for economic reasons, the German railway company shortened the glass roof and installed a flat ceiling, designed by another architect, significantly altering the appearance. Von Gerkan described the dispute as the most acrimonious in his 40-year career, claiming the changes amounted to a botched job that dented his pride. The judge ruled in favour of the architect, stating that the alteration was akin to ripping pages from a novel, and held that the building, as a work of art, had been considerably defaced (Lauterbach, 2011) (Figure 6).

In contrast, in the case of Pragati Maidan, Delhi, urban planning requirements were deemed to outweigh the architect's moral rights. The key issue was whether an architect could object to the demolition of their creation by the structure's legal owner. The case concerned the Hall of Nations, designed by architect Raj Rewal and recognised as an iconic modernist Indian architectural masterpiece.

Figure 6: The Berlin Central Station
Source: https://donges-steeltec.de/referenzen/berlin-central-railway-station-lehrter-station

The owner, the India Trade Promotion Organisation (ITPO), proposed demolishing the entire complex to construct an 'Exhibition-cum-Convention Centre' aimed at increasing space utilisation.

Raj Rewal filed a case against the demolition of the Hall of Nations (Figure 7), Hall of Industries and Nehru Pavilion, arguing that they were works of national artistic significance (Shaikh, 2022). The International Union of Architects (UIA), representing over 1.3 million architects across 120 countries, along with the Indian Institute of Architects, appealed to the Indian government to prevent the demolition. However, the verdict favoured ITPO, asserting that the property owner should not be disadvantaged by ownership and that the court applies law to facts, not emotions (Deeksha, 2018).

Figure 7: The Hall of Nations
Source: https://www.architectural-review.com/

7. IP PROTECTION IN INDIA

Effective copyright law aims to protect architects' interests, reward their creativity and prevent unauthorised usage or copying of their designs. Moreover, a clear and stringent action plan against

infringement is essential (Mann, 2010). The Indian government safeguards architects' copyrights through the Indian Copyright Act, 1957 ('the Act') and the Copyright Rules, 2013 ('the Rules').

Section 13 of the Act states that artistic works are eligible for copyright protection, while Section 2(b) defines a work of architecture as any building, structure or model with artistic design or character. Section 2(c) further defines "artistic work" to include a drawing, painting or sculpture in a map, diagram, chart, plan, photograph, engraving, architectural work or any other form of artistic creation.

India is a signatory to both the Berne Convention and the Universal Copyright Convention. Consequently, artistic works protected in other Berne signatory countries automatically receive protection in India, even without registration. Section 57 of the Act considers the moral rights of the creator of an architectural work or artwork, including the rights of attribution and integrity (Ghonim & Eweda, 2011).

The Designs Act, 2000, and the corresponding Designs Rules, 2001 (enforced from May 2001), govern the protection and registration of industrial designs in India. These rules were amended by the Designs Rules (Amendment) 2008 and 2014, with the latest amendment commencing in December 2014. According to Section 2(d) of the Designs Act, "design" refers to the shape, configuration, pattern, composition or ornamentation using lines or colours applied to a product in two-dimensional, three-dimensional or both forms.

New and original designs can be registered under the provisions of the Designs Act, 2000. Here, the term "original" denotes a design that originates from the author, including designs with novel applications. The Copyright Act offers protection for the author's lifetime plus an additional 60 years, whereas the Designs Act grants protection for a maximum of 15 years (Swarup & Rastogi, 2022). Designs that are eligible for registration under the Designs Act but are not registered may still receive protection under the Copyright Act, 1957 (Asarpota & Sharma, 2021).

Architects enjoy various intellectual property rights, as summarised in Table 1.

Table 1: IP protection for Architects
Source: Author

Ownership
• The architect possesses the copyright of the drawings and any documentation produced during the project, whereas a builder cannot claim copyright even if he builds it.
• However, where an architect is an employee, copyright automatically resides with the employer.
• The appointment agreement generally enables the client to use designs, but drawings could be used to seek planning permissions but not to construct the works without the architects' permission.
• If a client sells a site with planning permission, the designs used to apply for planning permission may not be available to construct the design without the architect's permission.
• If a client proceeds to develop a design with another designer, they may not be able to use that design, despite it is modified, without the creator's permission.
Additions or modifications to original plans
• Making additions or modifications to a plan or work will not avoid infringing copyright, especially when distinctive or important elements of the original plan or work are replicated in the "new "plan.
• The plan need not be reproduced in its entirety to infringe copyright - even if a plan replicates a small part of a copyrighted plan, if the small part contains an important feature or element of the original plan, this may be viewed as infringing copyright.
Authorization
• The architect can authorize a third party to use his copyrighted materials, but he retains the copyright.
• An architect can license a client or other design professionals for drawing's use , however the copyright typically dwells with the architect who created them.
The client sells the land
• The client sells the land to a third party and asks the architect to supply drawings (including CAD) to another architect appointed by the third party. The new owner is not the ' the copyright owner of the drawings,' reflecting the position without any contract; the architect holds the drawing's copyright but licenses it to the client.

8. IPR IN ACADEMICS

Copyright protection is an important aspect of academia in India. Although it has existed for over 150 years, it has not received the prominence or attention it deserves. Copyright in literary works was conceptually introduced in the nineteenth century in India, primarily through the licensing of books for publication.

Plagiarism, fabrication and data falsification are forms of academic misconduct. Academics with artificially inflated curricula vitae, often resulting from plagiarism, may undeservedly gain privileges such as academic degrees, titles, grants and promotions (Biagioli, 2012). The intellectual property rights (IPRs) applicable in academic contexts are summarised in Table 2.

Plagiarism can seriously damage an individual's professional career, as demonstrated in Germany, where a wave of plagiarism cases struck the political sphere after doctoral dissertations were found to contain copied material, leading universities to revoke the degrees of several politicians (Tudoroiu, 2017).

Table 2: IPR in Academics
Source: Gertz, 2013; Lipinski, 2003

Student's IPR
Students are considered inventors of any work produced, including legal documentation such as patent applications. However, the University or Institute retains a non-exclusive, irrevocable, royalty-free right reproduce, use, modify, and distribute student work for marketing, publicity, and enhancing their reputation without commercial gain. An acknowledgment of the University is required to use of work produced by a student at an Institute or University outside during their study or after they have left.
Theses and dissertations:
student's research theses and dissertations come under the class of literary works entitled to copyright protection. Copyright in the thesis and dissertations rests with the author, i.e., the students or the research scholar who has produced it, unless ownership of copyright is not transferred to another. The 1957, Copyright Act facilitates students suing for copyright infringement relating to their thesis. In the thesis, an adequately acknowledged and referenced short copyright material does not necessarily need permission from the owner.
Students as Employees
A professor pursuing research is often helped by an undergraduate/postgraduate student for fieldwork. In such a case, students do not have any copyright; however, If they create drawings/ details, the professor or researcher needs an NOC from the student.
Professors and research guide's role
The professor cannot use data from the student's thesis for their publications without the student's permission. However, without the Institute's permission, students do not need permission to use data from their thesis for their publications. Indeed, the guides or supervisors continually contribute to shaping the thesis with invaluable inputs, and guidance for the research. A supervisor or a guide's guidance is not covered under copyright protection, and they must acknowledge and give due respect to their scholar's research work .
Electronic and Distance Education Materials:
All original works submitted by the contributors for electronic and/or distance education course development remain the property of the concerned contributors and the Institute. The Institute has the right of using the course contents (including all related materials) developed by the faculty member and other employees involved in the development of a distance learning and e-learning course for the Institute's own educational, research, and other purposes without any additional compensation to the faculty member or any other employee who is an author of the course.
Publications:
Any publication, document, and paper arising from research activities is jointly owned by the Institute and the researcher. Without prior written permission from the institution, using the Institute's name, logo, or official emblem is not allowed. The Institute may retain the right to require the exclusion of certain portions from the information being published.

Research shows that 20 to 30 percent of international students—mainly from Southeast Asia, including India—studying in the US, UK and European universities engage in plagiarism and face severe consequences. Students often copy material from websites or printed textbooks, unaware of the risk of detection. Furthermore, their lack of awareness about strict university policies and the enforcement of zero-tolerance approaches to plagiarism leads them to take it lightly.

8.1 Penalties for copyright infringement

Violation of the Copyright Act by an independent researcher or author through plagiarism is considered a legal offence and may lead to prosecution in a court of law. Penalties vary depending on the severity of the offence and can include a range of legal and academic consequences (Putter, 2005). The penalties for academic misconduct are summarised in Table 3.

9. METHODOLOGY

An understanding of the current status of IPR awareness, knowledge and attitudes within the architectural fraternity is explored in this study. The work is informed by the Theory of Reasoned Action (TRA), which addresses theoretical constructs focused on individual motivational factors as key determinants in opting for intellectual property (IP) protection.

According to TRA, the process of adopting a new concept begins with awareness—when an individual first recognises the existence of the concept and begins to form preliminary perceptions about its attributes. Adoption or use is driven by an individual's behavioural intention, which in turn is influenced by their attitude towards performing the behaviour and by associated subjective norms. In this context, subjective norm refers to a person's normative beliefs that shape their perception of approval or disapproval regarding the behaviour. This includes the presence of a supportive environment and enabling conditions (Montano & Kasprzyk, 2015).

A questionnaire survey was conducted to examine architects' levels of awareness, attitudes, behavioural intentions and subjective norms that may influence their willingness to seek IPR protection. The sample consisted of 186 respondents, including architectural practitioners and academicians. The results of the data analysis are presented in the following section.

10. FINDINGS AND DISCUSSION

10.1 Knowledge and Awareness

This section examines general knowledge about IPR, along with specific awareness regarding the applicability of trademarks and copyrights in architecture, IP protection for international and national buildings and structures, monuments and interior layouts.

The analysis indicated that over 33% of respondents did not clearly understand copyright or trademarks, and 30% had only some knowledge. Respondents demonstrated limited awareness of buildings and monuments with IPR protection outside India. However, 41% were familiar with Indian buildings that have IP protection, while 45% reported no awareness.

Table 3: Penalties for academic misconduct
Source: Putter, 2005

Penalties for academician	
1	Disgrace to both Individual and institution
2	May face disciplinary action as per institute rules
3	It can cost a person his or her professional credibility or even a job
4	Debarment from eligibility to receive research funds for grants and contracts from any government agency in India
Penalties for student/research scholar	
1	Written apology
2	Rewriting or alternate piece of work
3	Rustication, temporarily or permanently for further higher education.
4	Restriction in publication of thesis or any chapter as article
5	Deduction of marks (Partial or Full)
6	Withdrawal of degree
7	Imposing Fine

Similarly, only 39% of respondents were aware of IP protection for store layouts, whereas 61% lacked this knowledge. It was noted that just 46% had limited knowledge about IPR protection for architectural drawings and concepts. Furthermore, only 24% were aware of their IPR as employers or employees, 16% knew about the existence of the 2002 Copyright Act, and just 13% understood their IPR responsibilities towards clients (Figure 8).

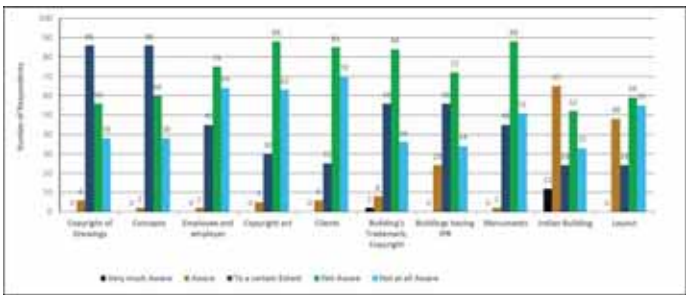


Figure 8: Knowledge and Awareness
Source: Author

10.2 Attitude and Subjective Norms

This section evaluates respondents' willingness to use IPR, their perception of its importance and relevance, trust in IPR laws and the availability of facilitating conditions.

Many respondents viewed the concept of IPR in architectural creation as abstract. The data revealed that 55% of respondents did not intend to seek legal protection for their designs, while only 24% were willing. This reluctance was largely attributed to a lack of ownership over their designs and minimal IPR awareness.

Only 30% of respondents considered IPR important and relevant to the architectural discipline. A considerable number expressed distrust in the legal system and doubted the enforcement of IPR laws in India. The absence of facilitating conditions, such as legal precedents, was highlighted by 40% of the respondents. While many acknowledged the importance of protecting their designs, they lacked adequate knowledge of how to obtain IP protection (Figure 9).

10.3 IPR in Academics

The study also investigated respondents' understanding of IPR in academic contexts, including issues related to plagiarism, citation practices, penalties for academic misconduct, IP protection for theses and student projects, and joint research initiatives.

The findings revealed poor knowledge of plagiarism and proper citation in academic research and publication, with only 23% of respondents being

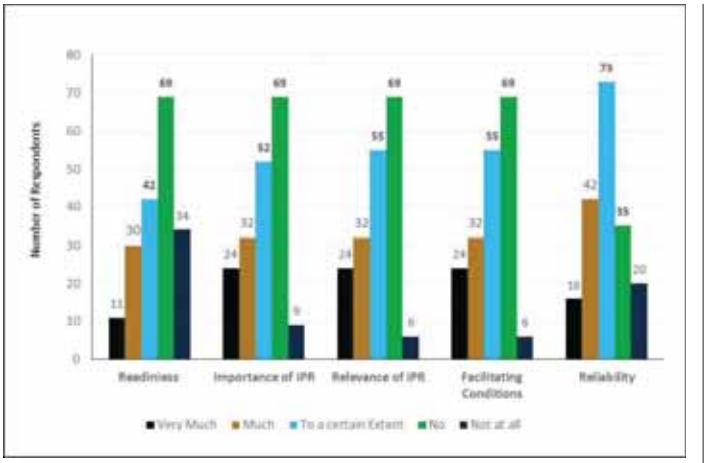


Figure 9: Attitude and Subjective Norms
Source: Author

informed. In contrast, 52% lacked such knowledge, which is a matter of concern. Only 12% of respondents were aware of penalties for academic misconduct, while 58% were unaware and 29% had partial knowledge.

Knowledge about IP protection for students' theses and research projects was particularly low, with only 3% demonstrating clear understanding and 85% showing complete unawareness. Similarly, 62% of respondents were unfamiliar with IP issues in joint research with students, 34% had some knowledge and only 4% were well-informed (Figure 10).

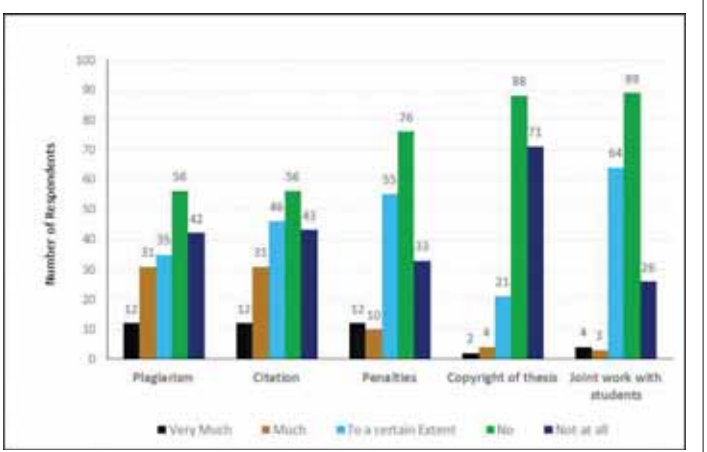


Figure 10: IPR in Academics
Source: Author

11. CONCLUSION AND RECOMMENDATIONS

Intellectual Property Rights (IPR) aim to protect and promote innovation and creativity. Despite the significant role of IPR in advancing research and innovation, its application in the architectural discipline remains largely untapped and faces numerous challenges in India. The unique nature of architectural works—which comprise both tangible and intangible elements—makes the implementation of IPR complex.

In addition to the gaps in the Indian Copyright Act concerning architects' moral rights, the protection of architectural works is situated on precarious and uncertain legal ground. Limited IPR application is further compounded by a general lack of awareness among architects, referring to their insufficient understanding of what IPR is, why it is important and how it should be protected and enforced.

The analysis revealed varying levels of IPR awareness, particularly regarding intellectual property and its legal implications. Many architects believe that IP protections are not always necessary or beneficial in the creative environments in which they work. Moreover, they expressed scepticism about obtaining IP protection due to limited resources and institutional support. Low IPR awareness in academic contexts results in a lack of protection, which is a key driver of high infringement rates.

According to Protection Motivation (PM) Theory, members of the architectural fraternity are more likely to seek IP protection if they recognise that their creativity is vulnerable to infringement and if they believe they are capable of taking action to secure their rights through legal measures.

This study addressed the neglected area of IPR in the architectural discipline, highlighting the urgent need to reinforce IPR sovereignty in the field. It emphasised the importance of creating a supportive environment that encourages architects to safeguard their intellectual property and fosters positive attitudes towards IPR in architectural practice. IPR education can motivate academicians to adopt protective measures and promote ethical academic behaviour. Legal IP protection is available in India for a wide range of architectural works and academic outputs, and it is imperative that both practitioners and academicians actively utilise these safeguards to prevent negative consequences for architectural practice and education.

REFERENCE

1. Adibfar, A., Costin, A., & Issa, R. (12020). Design copyright in architecture, engineering, and construction industry: Review of history, pitfalls, and lessons learned. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction.
2. Ahmed, S., & Varun, P. (2017). Awareness regarding intellectual property rights: A survey amongst the PG and Ph.D. students of Babasaheb Bhimrao Ambedkar University, Lucknow. Int J Law, 184–90.
3. Alghail, A., Abbas, M., & Yao, L. (2023). Where are the higher education institutions from knowledge protection: A systematic review. VINE Journal of Information and Knowledge Management Systems, 387–413.
4. Asarpota, N., & Sharma, M. (2021). A Critical Analysis of Design Protection Laws in India. Indian JL & Legal Rsch, 1–8.
5. Bently, L. (2017). Copyright, translations, and relations between Britain and India in the nineteenth and early twentieth centuries.
6. Chi.-Kent L. Rev, 1181. Bhat, S. R. (2018). Innovation and intellectual property rights law—An overview of the Indian law. IIMB Management Review, 51–61.
7. Biagioli, M. (2012). Recycling texts or stealing time?: Plagiarism, authorship, and credit in science. International Journal of Cultural Property, 453–476.
8. Booth, G. (2015). Copyright law and the changing economic value of popular music in India. Ethnomusicology, 262–287.
9. Bradford, L. (2015). Inventing patents: A story of legal and technical transfer. West Virginia Law Review, 267–324.
10. Das, A. (2015). An Analytical Study of Indian Copy Right Act, 1957 and Copyright Bill 2012. International Journal of Innovative Research in Science, Engineering and Technology.
11. De Rosnay, M. D., & Langlais, P. (2017). Public artworks and the freedom of panorama controversy: A case of Wikimedia influence. Internet Policy Review.
12. Deeksha, P. (2018). CASE COMMENTARY RAJ Rewal vs. Union of India & Ors. CS (COMM). Indraprastha Law Review, 1–5.
13. Devasena, S. V. (2024). Bridging the Gap: A Comparative Analysis of Intellectual Property Rights Awareness and Institutional Initiatives among Male and Female Engineering College Students. Educational Administration: Theory and Practice, 1264–1268.
14. Gertz, G. A. (2013). Copyrights in faculty-created works: How licensing can solve the academic work-for-hire dilemma. Wash. L. Rev, 1465. Ghonim, M. N., & Eweda, N. (2011). Architectural copyright potentialities and limitations with a special reference to Egypt. Journal of Engineering and Applied Science, 181–196.
15. Hughes, J. (2011). A short history of intellectual property in relation to copyright. Cardozo L. Rev., 1293.
16. Kapczynski, A. (2007). The access to knowledge mobilization and the new politics of intellectual property.
17. Yale LJ, 117, 804. Kurz, P. (2023). Brunelleschi and Galilei: Super-Early Patents in Florence and Venice. 8th IEEE History of Electrotechnology Conference (pp. 143–146). Venice: HISTELCON.
18. Lauterbach, T. (2011). Author-architects and the moral right of integrity in copyright law. South African Journal of Art History, 57–66.
19. Lee, Y. (2011). Understanding anti-plagiarism software adoption: An extended protection motivation theory perspective. Decision Support Systems, 361–369.
20. Lipinski, T. A. (2003). Legal issues in the development and use of copyrighted material in web-based distance education. Handbook of Distance Education, 481–505.

21. Long, P. O. (1991). Invention, authorship, "intellectual property," and the origin of patents: Notes toward a conceptual history. Technology and Culture, 846–884.
22. MacMurray, R. (2004). Trademark or Copyrights: Which Intellectual Property Right Affords Its Owner the Greatest Protection of Architectural Ingenuity. Nw. J. Tech. & Intell. Prop, 111.
23. Mann, P. (2010). Who Owns The Copyright Of Architectural Works And Designs. School of Construction Management and Engineering, University of Reading, 733–748.
24. May, C. (2002). The Venetian moment: New technologies, legal innovation and the institutional origins of intellectual property. Prometheus, 159–179.
25. Montano, D. E., & Kasprzyk, D. (2015). Theory of reasoned action, theory of planned behavior, and the integrated behavioral model. Health Behavior: Theory, Research and Practice, 231.
26. Moon, H. (2007). A Brief Sketch of Architectural Works Copyright with the United States Cases: Analysis based on Thomas Shine v. David M. Childs and Skidmore Owings & Merrill, LLP Case. Architectural Research, 1–8.
27. Mossoff, A. (2012). Saving Locke from Marx: The labor theory of value in intellectual property theory. Social Philosophy and Policy, 283–317.
28. Nair, J. S. (2024). Exploring Possibilities for a Right against Destruction for Architects. Christ University Law Journal, 59–85.
29. Nemlioglu, I. (2019). A comparative analysis of intellectual property rights: A case of developed versus developing countries. Procedia Computer Science, 988–998.
30. Olaisen, J., & Revang, O. (2017). The dynamics of intellectual property rights for trust, knowledge sharing and innovation in project teams. International Journal of Information Management, 583–589.
31. Özeren, Ö., Qurraie, B., & Eraslan, M. (2024). Preserving Cultural Heritage with Digital Design and NFT Technologies: Innovative Approaches in Architectural Education. DEPARCH Journal of Design Planning and Aesthetics Research, 161–175.
32. Pappalardo, K., & Meese, J. (2019). In support of tolerated use: Rethinking harms, moral rights and remedies in Australian copyright law. University of New South Wales Law Journal, 928–952.
33. Plomer, A. (2013). The human rights paradox: Intellectual property rights and rights of access to science. Human Rights Quarterly, 43–175.
34. Putter, J. (2005). Copyright Infringement v. Academic Freedom on the Internet: Dealing With Infringing Use of Peer-to-Peer Technology on Campus Networks. Journal of Law and Policy, 13.
35. Rout, S. K. (2018). A brief review on intellectual property rights with special attention on patent. Journal of Applied and Advanced Research, 73–77.
36. Ruhtiani, M., Prihatinah, T., Sulistyandari, S., Park, H., & Whindari, Y. (2024). Legal Protection of Architectural Works as Copyright: An Epistemological and Islamic Law Perspective. El Mashlahah, 43–70.
37. Schroeder, J. L. (2005). Unnatural rights: Hegel and intellectual property. U. Miami L. Rev., 453.
38. Shaikh, S. (2022). Protection of Architectural Design under Intellectual Property Rights. us Corpus LJ, 1013.
39. Shipley, D. E. (2010). The Architectural Works Copyright Protection Act at Twenty: Has Full Protection Made a Difference?
40. J. Intell. Prop. L. Spence, A. T. (2000). When a Landmark Cannot Serve as a Trademark: Trademark Protection for Building Designs in Light of Rock and Roll Hall of Fame and Museum. Wash. UJL & Pol'y, 517.
41. Swarup, S. K., & Rastogi, S. (2022). Fashion design and intellectual property rights: An Indian Perspective. Journal of Intellectual Property Rights (JIPR), 127–135.
42. Tudoroiu, T. (2017). No, prime minister: PhD plagiarism of high-level public officials. European Review, 623–641.
43. Vacca, A. (2005). The Architectural Works Copyright Protection Act: Much Ado about Something. Marq. Intell. Prop. L. Rev.
44. Witty, M. (2017). Athenaeus describes the most ancient intellectual property. Prometheus, 137–143.

Dr. Vasudha A Gokhale (AII084) has a B.Arch. from MANIT, Bhopal, and an M.Arch. and PhD from IIT, Roorkee. She has been a visiting scholar at the University of Melbourne and New Zealand. She is a Professor and Head of PhD Research Centre at B.N.C.A. Pune. Fourteen candidates have been awarded Ph.D. degrees under her supervision. She has more than 175 publications to her credit.
Email: gokhale.va@gmail.com

An Analytical Study on Low-Carbon Residential Buildings in the Composite Climate of India

By Ar. Akshay Sanyal and Dr. Nirmita Mehrotra

1. Introduction

In a globalising world, the housing industry significantly influences energy usage, economic patterns, climate change and societal trends (Chen et al., 2011). The rapid construction of high-rise buildings facilitated by technological advancements in the construction sector has accelerated the depletion of non-renewable resources (Omer, 2014). Residential buildings, notably in composite climates, significantly contribute to carbon emissions and energy consumption (Mostafavi et al., 2021). Residential buildings in India are responsible for 50% of the country's total energy use (Nejat et al., 2015). In the present scenario, Greater Noida has become a crucial example in understanding the climate change impact and addressing the carbon loading in residential buildings in Indian composite climate (Jain, 2023). Buildings can be retrofitted and energy efficiency can be improved and sourced from renewables as effective measures. To create effective carbon reduction strategies, it is imperative to comprehend residents' energy behaviours and comfort perceptions (Ding et al., 2018). Prioritising residential buildings in energy conservation and carbon reduction efforts is vital for achieving low carbon emissions in Indian buildings.

1.1 Aim and objectives

This research aims to study the carbon loads associated with residential buildings in a composite climate region, specifically within India. To achieve the aim, the following objectives have been formulated for this study.

a. To assess the contribution of construction materials, energy consumption and operational behaviour to the carbon footprint of residential buildings.

b. To analyse the literature reviews and case studies for similar projects on low-carbon building projects.

c. To identify climatic potential for reducing carbon emissions in residential buildings in similar climate zones.

d. To provide insights for policymakers, architects, builders and residents for decarbonising construction and operation practices.

1.2 The highlights of the research

a. **Study Location:** Greater Noida, Uttar Pradesh, in a composite climate zone.

b. **Purpose:** Assess and analyse carbon loads of residential buildings in the region.

c. **Methodology:** Combination of field surveys, data collection, computer-based simulation and energy modelling.

d. **Scope:** Covers aspects like construction materials, energy consumption and occupant behaviour.

e. **Diversity:** Includes a wide range of housing types and construction methods in Greater Noida.

f. **Complex Factors:** Carbon loads influenced by building design, orientation, insulation and renewable energy usage.

g. **Occupant Behaviour:** Resident behaviour and lifestyle choices impact carbon emissions.

h. **Implications:** Sustainable design and construction practices for architects and builders.

i. **Sustainability:** Contributes to understanding carbon footprints and suggests carbon reduction strategies.

j. **Broader Relevance:** Insights extend beyond Greater Noida, offering lessons for sustainable construction in similar climates worldwide.

2. Low-Carbon Buildings in India – A Literature Review

India, characterised by its rapidly burgeoning economy and population, confronts substantial challenges in balancing its energy demands with the imperative of curtailing carbon emissions (Batra, 2023). The construction sector in India is a major contributor to energy consumption and greenhouse gas (GHG) emissions, utilising around 30% of the country's total energy and generating about 20% of its GHG emissions (Huang et al., 2018).

In response to these challenges, India has made a commitment to reduce its carbon emissions intensity by 32–36% from 2006 levels by 2035 and to raise the proportion of non-fossil fuel-based energy sources to 45% by 2035 (Gadre & Anandarajah, 2019). This will require a significant transformation of the building sector, including the implementation of building technologies and practices that have low carbon emissions.

When considering green building residential houses in India, two key frameworks come into play: EcoNiwas Samhita (ENS) and GRIHA (Green Rating for Integrated Habitat Assessment). EcoNiwas Samhita, developed by the Bureau of Energy Efficiency (BEE) under the Ministry of Power, is India's energy conservation building code specifically for residential buildings. It sets minimum performance standards primarily focused on the building envelope (walls, roof, windows) to limit heat gain and loss, ensuring energy efficiency. On the other hand, GRIHA, developed by The Energy and Resources Institute (TERI) and endorsed by the Ministry of New and Renewable Energy (MNRE), is a more comprehensive green building rating system that assesses a wider range of sustainability parameters across a building's lifecycle, including site planning, water and waste management, materials, and indoor environmental quality, ultimately providing a star rating to certify the overall environmental performance of a residential project. While ENS provides foundational energy efficiency guidelines, GRIHA offers a holistic certification for truly green residential developments.

2.1 Case Studies of Low-Carbon Buildings in India

Several case studies of low-carbon buildings in India have been conducted, showcasing the capacity for substantial reductions in energy consumption and GHG emissions. Some notable examples include:

a. **The Energy Research Institute (TERI)** headquarters in New Delhi: This building is designed to achieve up to a 55% reduction in energy consumption compared with a conventional building. It uses a number of energy-efficient features, including a high-performance building envelope, natural ventilation and energy-efficient lighting and appliances (Singh & Prasad, 2000).

b. **The Indian Green Building Council (IGBC)** - a Platinum-rated building in Hyderabad: The energy consumption of this building is designed to be 42% lower than that of a conventional building. It uses a number of energy-efficient features, including a high-performance building envelope, a solar photovoltaic (PV) system and energy-efficient lighting and appliances (Marimuthu, 2012).

c. **The CII-Godrej Green Business Centre** in Hyderabad: The energy consumption of this building is designed to be 30% lower than that of a conventional building. It uses a number of energy-efficient features, including high-performance building envelopes, a solar PV system and energy-efficient lighting and appliances (Wani & Mushtaq, 2018).

d. **The House Under Shadows in Karnal, Haryana,** in a part of the National Capital Region (NCR), India: is a remarkable residential project designed by Zero Energy Design Lab (ZED Lab). It's an excellent example of a near-net-zero building that integrates sustainable design principles with traditional Indian architectural elements.

The analysis of existing research on low-carbon buildings in India reveals significant opportunities for decreasing energy consumption and greenhouse gas emissions within the construction industry. However, there are also several knowledge gaps and areas for further research. For instance, data gap in the building sector. India's building sector lacks comprehensive data on energy consumption and greenhouse gas emissions. This gap hinders the precise evaluation of potential energy savings and

GHG emissions reductions (Geelani et al., 2012). India also lacks research on the cost effectiveness of low-carbon building technologies. This makes it difficult to determine the financial feasibility of adopting these technologies. A critical need exists for a more comprehensive collection of case studies on low-carbon buildings in India. Expanding the pool of case studies will illustrate the potential for energy conservation and greenhouse gas (GHG) emission reductions across various building types and climatic conditions (Chaturvedi, et al., 2024).

3. Data Survey and Analysis

3.1 Questionnaire Investigation

The online questionnaire-based study in India aimed to conduct a statistical survey to examine the characteristics of residential buildings, energy consumption patterns and the thermal comfort levels of urban residents. The survey was conducted between April and August 2023 and involved the distribution of 300 paper questionnaires, of which 220 were returned. The returned questionnaires were then analysed, with a specific focus on site areas. After removing invalid questionnaires, 100 usable questionnaires were obtained for analysis.

3.2 Investigation Method

This research employed a multi-criteria filtering process to choose cities in the NCR zone and randomly sampled data from each selected city to gain a more comprehensive grasp of crucial data such as thermal comfort, building information and energy conservation. Following data categorisation and extraction, a questionnaire was distributed and data processing was carried out. This study introduces three widely used and practical data processing methodologies:

Samples deletion: This approach is frequently employed when a questionnaire doesn't have any answers; therefore, it should be excluded.

Partial deletion: The statistical validity of other variables is not affected when data for a specific variable is excluded from analysis due to unanswered questions in a questionnaire.

Modify: When values are missing, imputation is a common strategy. For variables with less than 5.67% missing values, missing values can be imputed with the variable's mean. However, for variables with more than 5% missing values, a "hot deck" approach is recommended. In this approach, individuals with similar characteristics are grouped and the mean of the group is used to impute the missing values for each individual in the group.

3.3 Household Features: Observations from the Questionnaire Survey

The key points of the questionnaire are shown in Table 1. A 6-stage sampling method was designed to ensure the objectivity and effectiveness of the survey data. In India, residential buildings are commonly classified into three categories based on the height of the structure - detached houses (consisting of one to three stories), multi-story dwellings and high-rise dwellings, as shown in Table 2. As shown in Figure 1, the occupancy rates for the three residential building types differ significantly across the surveyed cities, according to the survey results. Approximately half of the respondents (50%) reside in high-rise dwellings, while a third (33.33%) live in multi-story dwellings and only 16.67% reside in detached houses.

The survey considered the construction age of selected residential buildings in three cities. Figure 2 shows the distribution of construction ages for

Table 1: Related basic information for consideration
Source: Author

Objectivity of the data survey	Effectiveness of the survey data
Location of the Building	Area of the Building
Number of Occupancies	Time of Construction
Building Structure	Window and Wall Area

Table 2: Correlation between the classification of structures and their number of floor
Source: Author

Type of Building	Number of floors
Detached House	1-3
Multi-Story Residence	4-6
High-rise Residence	7+

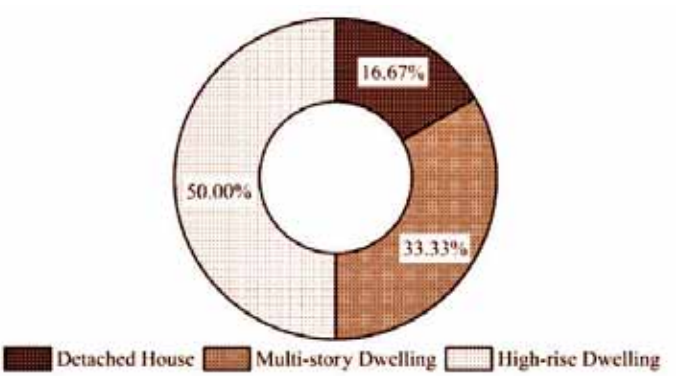


Figure 1: Building types and their relative numbers
Source: Author

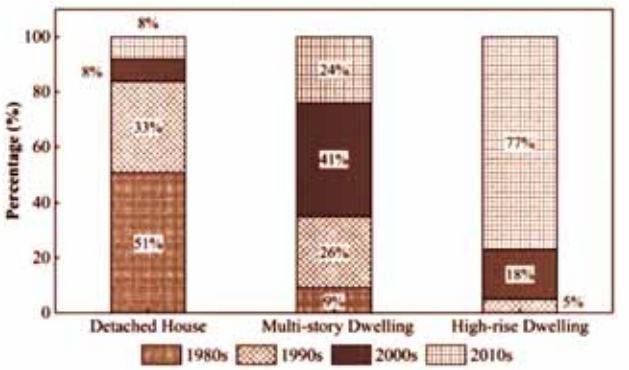


Figure 2: Distribution of survey for the occupancy ratios of the three residential buildings.
Source: Author

the selected buildings. Buildings constructed after the 1990s were primarily multi-story and high-rise dwellings, while those built before the 1990s were mainly low-rises. The mean average area for each building type was also calculated. Detached houses had the largest mean average area at 121 m^2/household, followed by high-rise dwellings at 118 m^2/household and multi-story dwellings at 106 m^2/household. As for window area, detached houses consistently had the largest windows (Figure 3).

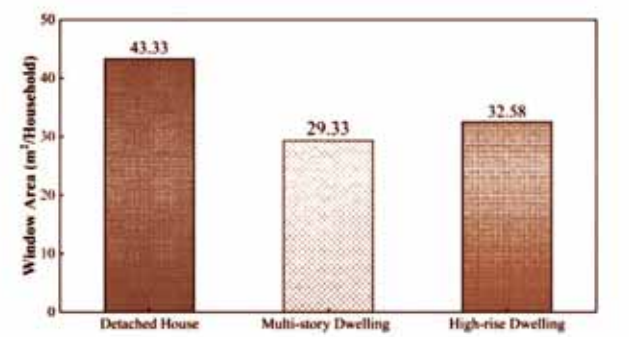


Figure 3: Typical Window Area for Three Buildings.
Source: Author

4. Building Carbon Emissions in Composite Climate

The composite climate is unique because it experiences extreme variations in temperature throughout the year. In summers, the temperature can reach up to 45°C or higher, while in winters, the temperature can drop below 5°C. The annual rainfall in this zone ranges from 500 to 1000 mm and the rainy season usually lasts from June to September. Thus, composite climate in India is characterised by a high annual temperature range, hot summers and cool winters with low to moderate rainfall. This climatic zone is found in the central and northern parts of India, covering regions such as Delhi, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Rajasthan and parts of Maharashtra. The following points summarise the composite climatic data in India.

a. Region Coverage: Mostly the central region of India is covered.

b. Predominant main seasons: Warm and Humid, Hot and Dry.

c. Cities: New Delhi, Kanpur, Bhopal, Raipur and others

d. Average Temperature: During summer - 31°C-43°C (day time), 28°C-32°C (night time)

   During winter - 12°C-25°C (day time), 5°C-10°C (night time)

e. Humidity ranging from 20-25% in dry periods to 55-95% during wet periods.

f. Ecological topology consisting of a variable landscape and seasonal vegetation.

g. Solar radiation reaches high intensity in the summer and low intensity during the monsoon season.

h. Precipitation accumulating 500 to 1300 mm annually.

i. Sky conditions that are typically clear in the winter, dull during the monsoon season and frequently hazy in the summer.

j. Winds: Hot Dusty (Summer), Dry-Cold Winds (Winter), Strong (Monsoons)

In figure 4, the composite climate is characterised by extreme temperature variations, which pose significant challenges for building design and construction in the region. Buildings located in this climate should be built to maintain comfortable temperatures throughout both hot summers and

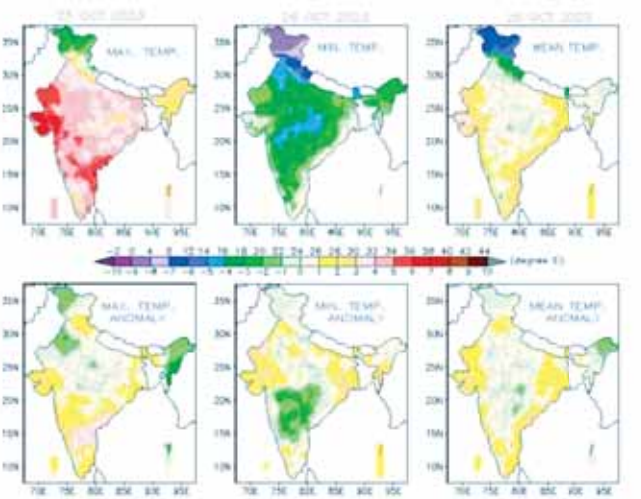


Figure 4: Daily Temperature Map of India
Source: Meteorological Department of India

cold winters, as well as withstand strong winds and occasional dust storms.

While the composite climate presents unique challenges for building design and construction, careful consideration of these challenges can lead to the creation of comfortable, energy-efficient and sustainable buildings. By implementing appropriate design strategies and selecting suitable building materials, buildings in this region can be well-adapted to their environment.

To maintain the precision and efficacy of climate data analysis particular to India, the New Central Region (NCR) has been chosen as a representative case study. This region will serve as a model for understanding composite climate patterns throughout the country, offering insights into the diverse climatic conditions experienced across India.

4.2 Climatic data of composite climate (Greater Noida, UP).

The city of Greater Noida, situated in the state of Uttar Pradesh, India, falls under the composite climate zone, characterised by hot and dry summers, warm and humid monsoons and cool and dry winters. Understanding the nuances of the local meteorological conditions is crucial for designing energy-efficient and comfortable low-carbon residential buildings in this region. The following elaborates on the key climatic parameters influencing building design.

In figure 5, sourced from the Meteorological Survey of India, provides a granular view of the daily average meteorological conditions throughout the year in Greater Noida. This comprehensive dataset likely includes parameters such as:

Figure 5: Daily average meteorological data of Greater Noida
Source: Meteorological Survey of India

1. **Dry Bulb Temperature:** It is the actual temperature of the air. Analysing the daily temperature variations helps in determining the heating and cooling loads of buildings across different seasons. The extreme summer temperatures necessitate effective cooling strategies, while the mild winters might require minimal heating.
2. **Relative Humidity:** It is the amount of moisture present in the air relative to the maximum amount it can hold at a given temperature. High humidity during the monsoon season can significantly impact thermal comfort and necessitate dehumidification strategies. Low humidity during the dry seasons can lead to discomfort due to excessive dryness.
3. **Solar Radiation:** It is the amount of solar energy received per unit area. Understanding the intensity and duration of solar radiation is vital for optimising building orientation, designing appropriate shading devices and harnessing solar energy for power generation.
4. **Wind Speed and Direction:** It is the speed and direction from which the wind blows. Analysing daily wind patterns helps in designing for natural ventilation, which can significantly reduce the reliance on mechanical cooling during favourable periods. Prevailing wind directions can also influence the placement of openings and the overall building form to maximise cross-ventilation.

A detailed examination of Figure 5 would reveal the specific daily fluctuations of these parameters, offering valuable insights for dynamic building performance simulations and the development of responsive design solutions.

The figure 6, adopted from *Climaticdata.org*, presents an overview of the annual temperature and rainfall patterns in Greater Noida. Key information derivable from this figure includes:

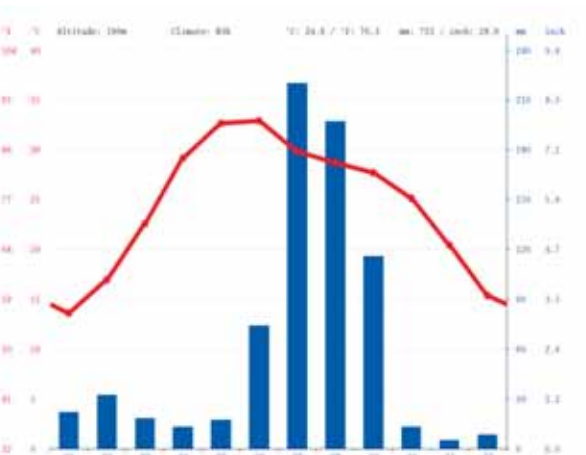


Figure 6: Annual data for temperature and rainfall in Greater Noida
Source: Climaticdata.org

1. **Monthly Average Temperatures:** Illustrating the seasonal variations in temperature, highlighting the peak summer months and the cooler winter months. This data is essential for calculating seasonal heating and cooling energy demands.
2. **Annual Rainfall Distribution:** Showing the total amount of rainfall received throughout the year and its distribution across different months. The majority of rainfall is expected during the monsoon season, which has implications for building envelope design to prevent water ingress and manage rainwater runoff. The dry periods highlight the need for water conservation strategies.
3. **Extreme Temperature Values:** Indicating the highest and lowest temperatures recorded, which are critical for designing building systems that can withstand climatic extremes and ensure occupant comfort and safety.

Analysing Figure 6 provides a broad understanding of the annual climatic cycle and its key drivers, temperature and precipitation, which significantly influence building design strategies.

The annual wind rose, likely generated using climatic consultant software, provides a visual representation of the frequency and intensity of winds blowing from different directions over a year in Greater Noida. This graphical tool is invaluable for:

1. **Identifying Prevailing Wind Directions:** The longer "petals" of the wind rose indicate the directions from which the wind blows most frequently. Orienting buildings and designing openings to face the prevailing winds can maximise the potential for natural ventilation, leading to reduced energy consumption for cooling.
2. **Assessing Wind Speeds:** The different segments within each petal typically represent varying wind speed ranges. Understanding the distribution of wind speeds helps in designing for effective ventilation without causing discomfort due to excessive drafts.
3. **Understanding Seasonal Variations:** While this figure represents the annual wind pattern, seasonal wind roses (if available) would provide a more detailed understanding of how wind patterns change throughout the year, allowing for more refined design strategies.

By analysing the wind rose in Figure 7, architects and engineers can make informed decisions regarding building orientation, placement of windows and ventilators and the design of airflow pathways to optimise natural ventilation and enhance thermal comfort within low-carbon residential buildings in Greater Noida.

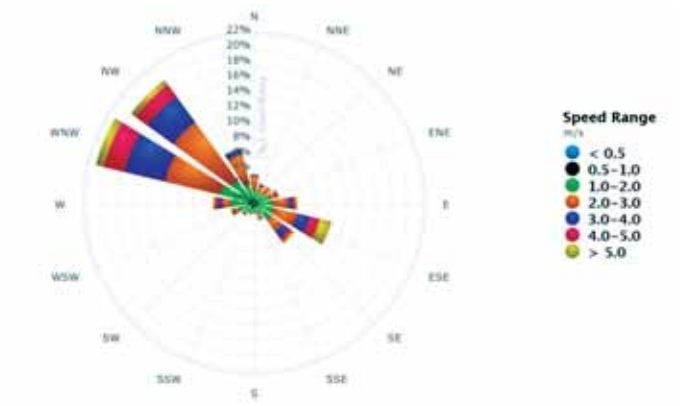


Figure 7: Annual Wind Rose of Greater Noida
Source: Climatic consultant software

The climatic data presented in Figures 5, 6 and 7 is fundamental for developing contextually appropriate and energy-efficient building designs in the composite climate of Greater Noida. Integrating these insights into the design process can significantly contribute to reducing the energy footprint of residential buildings and promoting sustainable development in the region.

5. Carbon Emissions in Residential Building

Residential buildings are a significant source of carbon emissions, accounting for a large proportion of global greenhouse gas emissions. This is due to the energy used to power and heat homes, as well as the materials used in building and maintaining them. The carbon load of a building refers to the quantity of carbon dioxide (CO_2) and other greenhouse gases released inside the building's indoor environment. This carbon emission originates from diverse sources such as occupants, building materials, appliances and HVAC systems.

High carbon load levels pose numerous health and well-being concerns for building occupants and environmental impacts. Elevated CO_2 levels cause headaches, fatigue and diminished cognitive abilities. Additionally, they contribute to climate change by trapping heat in the atmosphere (Urge-Vorsatz et al., 2013). The Global Status Report for Buildings and Construction (GSRBC) indicates that buildings contribute 39% of global greenhouse gas emissions. About 28% of this comes from the operation of buildings while 11% arises from building materials and construction. Reducing carbon emissions from buildings is essential to achieving net-zero emissions by 2050 and meeting the Paris climate goals.

5.1 Carbon Life-Cycle Assessment of a Building

Figure 8 illustrates the key stages in a building's life cycle, mapping them against common system boundaries for assessing embodied carbon. The life cycle begins with material extraction and progresses to material processing and component fabrication, the point defined as the 'Gate'. Materials are then transported to the 'Site' for construction and assembly. Once completed, the building enters its operation (service) phase, which includes use, maintenance and repair. Finally, it reaches its End-of-Life, involving demolition and waste management (landfill, recycling or reuse), marking the 'Grave'. A simplified flow diagram is shown below.

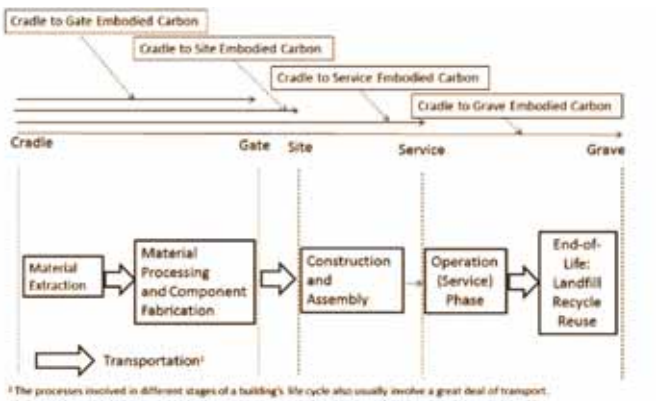


Figure 8: Adopted and updated Schematic diagram for Carbon Life-cycle Assessment
Source: Omer, 2008

Figure 8 highlights different scopes for measuring embodied carbon:

1. **Cradle-to-Gate:** Covers emissions from extraction through manufacturing.
2. **Cradle-to-Site:** Extends to include transportation to the construction location.
3. **Cradle-to-Service:** Includes the construction and assembly process.
4. **Cradle-to-Grave:** Represents the full life cycle, encompassing all stages shown.
5. **Cradle-to-Cradle:** New use of waste material by adding value to it.

Crucially, transportation is shown as an ongoing process, contributing to embodied carbon between each stage. This visualisation helps in understanding where embodied carbon emissions occur and the importance of defining clear system boundaries for life cycle assessments (LCA) in the construction sector.

A building's carbon life-cycle assessment (LCA) is an all-encompassing evaluation of the environmental effects associated with every phase of a building's existence, from the sourcing and processing of raw materials to the building's demolition and waste management. The primary focus of a carbon LCA is to quantify the greenhouse gas emissions (GHGs) released at each stage. By understanding the carbon footprint of a building, stakeholders can make informed decisions to minimise its environmental impact.

After using Energy Estimation Toolkit software for determining net energy (electricity) consumption, the sources of carbon emissions in residential buildings can be broadly categorised into two main categories: operational emissions and embodied emissions.

5.2 Operational Emissions

Operational emissions are generated by the day-to-day activities that take place within the building (Ibn-Mohammed et al., 2013). This includes energy consumption for heating, cooling, lighting and appliances. Some common sources of operational emissions in residential buildings include:

a. **Space cooling and heating:** Space heating is the biggest energy consumer in residential buildings, taking up approximately 42% of total energy use.

b. **Water Heating:** Heating water for showers, baths and other household needs accounts for around 15% of energy use in the residential buildings.

c. **Lighting:** Usage of lighting accounts for around 10% of energy used in residential buildings.

d. **Appliances and electronics:** The use of appliances and electronics such as refrigerators, washing machines and televisions accounts for around 30% of energy use in residential buildings.

5.3 Embodied Emissions

Embodied emissions are produced during the manufacturing, transportation and construction phases of building materials (Ibn-Mohammed et al., 2013). This includes energy and emissions generated in the production of materials such as steel, cement and glass, as well as the emissions generated during transportation and construction. Some common sources of embodied emissions in residential buildings are included in Figure 9.

6. Result and discussion

Overall, reducing carbon emissions in residential buildings requires addressing both operational and embodied emissions by improving energy efficiency,

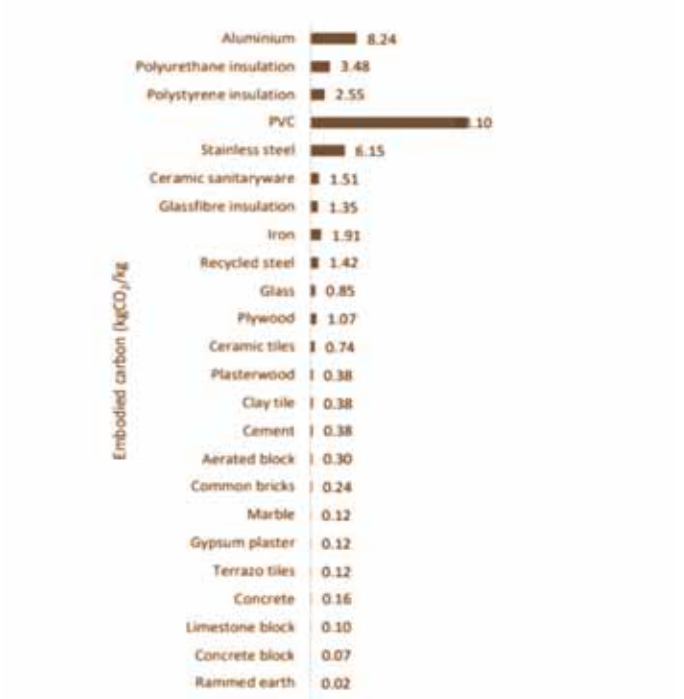


Figure 9: List of Embodied Carbon in the Building Material
Source: ICCC Database for India

using renewable energy sources and choosing low-carbon building materials.

To effectively reduce carbon emissions in residential buildings, a multifaceted approach is necessary, targeting both operational and embodied emissions. Operational emissions stemming from the day-to-day energy use of a building for heating, cooling, lighting and appliances can be significantly reduced through energy efficiency measures. This includes improving insulation and upgrading to energy-efficient windows and doors and using high-efficiency heating and cooling systems. Additionally, switching to renewable energy sources, such as solar panels or geothermal heat pumps, can drastically reduce operational emissions.

Embodied emissions, on the other hand, are associated with the extraction, production, transportation and disposal of building materials. To address these emissions, it's crucial to choose low-carbon building materials, such as sustainably sourced wood, recycled steel and low-carbon concrete. Implementing design strategies that prioritise material efficiency and minimise waste can also contribute to reducing embodied emissions.

Furthermore, considering the entire lifecycle of a building is essential for minimising its overall carbon footprint. This includes factors such as the building's adaptability for future uses, its potential for deconstruction and material reuse and the energy required for its maintenance and operation over time.

In Table 3, a comparison of building operation carbon emissions reveals a direct correlation with climatic types, primarily driven by the energy required for

Table 3. Comparison of Building Operation Carbon Emissions by Climatic Type
Source: Author

Climatic Type	Key Characteristics	Impact on Energy Consumption	Carbon Emissions
Hot and Dry	High temperatures, low humidity	High cooling demand, low heating demand	Higher operational carbon due to increased cooling
Hot and Humid	High temperatures, high humidity	High cooling and dehumidification demand	Higher operational carbon due to cooling and dehumidification
Temperature	Moderate temperatures, varying humidity	Balanced heating and cooling demand	Moderate operational carbon
Cold	Low temperatures, low humidity	High heating demand, low cooling demand	Higher operational carbon due to increased heating
Cold and Humid	Low temperatures, high humidity	High heating and dehumidification demand	Higher operational carbon due to heating and dehumidification
Composite	Hot and dry summers, warm and humid monsoons, and cool and dry winters.	Significant cooling demand in summer, moderate cooling and dehumidification in monsoon, and some heating demand in winter. Overall, high energy consumption due to seasonal extremes.	Higher operational carbon due to varied and substantial heating, cooling, and dehumidification needs across different seasons.

heating, cooling and dehumidification. In hot and dry climates, characterised by high temperatures and low humidity, the dominant energy demand comes from cooling, leading to higher operational carbon emissions. Similarly, hot and humid climates, with their high temperatures and humidity levels, necessitate significant energy for both cooling and dehumidification, resulting in elevated carbon emissions.

Temperate climates, featuring moderate temperatures and varying humidity, exhibit a more balanced need for heating and cooling, generally leading to moderate operational carbon emissions. Conversely, cold climates, defined by low temperatures and low humidity, experience a high demand for heating, which contributes to higher operational carbon emissions. When these low temperatures are combined with high humidity, as in cold and humid climates, the energy requirements for both heating and dehumidification increase, further escalating the operational carbon footprint.

Table 4 details the key drivers of carbon emissions in buildings, broken down into four main phases:

1. **Building Design**: Decisions made here, such as location/climate, orientation, window-to-wall ratio, insulation and overall building geometry, fundamentally determine a building's energy requirements and initial embodied carbon.
2. **Construction**: This phase's emissions are influenced by construction practices (especially waste management), the use of prefabrication and the transportation of materials to the site.
3. **Operation**: During the building's use, major factors include the integration of renewable energy, the efficiency of energy systems (like HVAC and lighting, which are major contributors), occupant behaviour and ongoing maintenance practices.
4. **Materials**: The choice of materials is critical, with considerations for their total embodied carbon (from extraction to disposal), the selection of low-carbon alternatives and the recyclability and durability of the chosen materials.

In essence, managing a building's carbon footprint requires a holistic approach, considering impacts at every stage from conception through its entire lifespan and eventual deconstruction or reuse.

6.1 Decarbonisation

Strategies to reduce carbon load in buildings include improving ventilation, utilising energy-efficient appliances and lighting and employing low-emitting building materials. Building owners and managers can also monitor indoor air quality to ensure that CO_2 levels and other pollutants remain within safe and healthy limits.

Carbon sinks, either natural or man-made, have the ability to absorb and store carbon dioxide (CO_2) from the atmosphere, alleviating its impact on global climate change. Carbon sinks are essential components of the carbon cycle, contributing to efforts to reduce the accumulation of greenhouse gases in the atmosphere. They can be categorised into two primary types: biological and geological. Figure 10 offers a compelling visual narrative of the historical and potential future shifts in global carbon pools, directly relating to the concept of carbon sinks and sources. It illustrates three distinct phases:

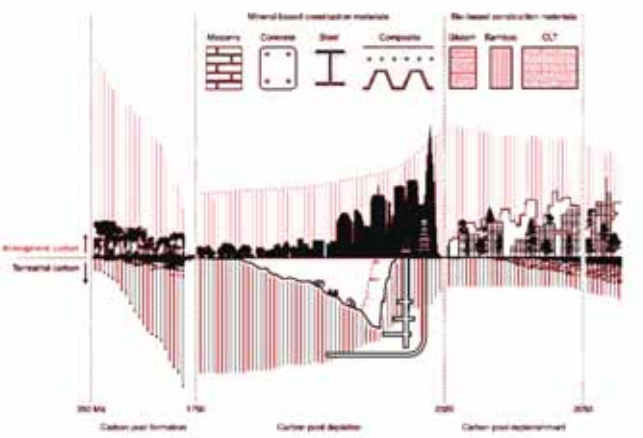


Figure 10: Building as a Global Carbon Sink
Source: Ang et al., 2023

1. **Carbon Pool Formation (Pre-1750):** This era shows a natural balance, with significant carbon stored terrestrially (biological and geological sinks) and a relatively stable atmospheric carbon level.
2. **Carbon Pool Depletion (1750-2020):** This period marks the industrial age, characterised by the large-scale extraction and use of fossil fuels (depleting geological sinks) and the prevalence of mineral-based construction materials like concrete and steel. The production of these materials is energy-intensive, releasing vast amounts of stored carbon and significantly increasing atmospheric CO_2 levels, as depicted by the rising black skyline and the shrinking terrestrial pool.
3. **Carbon Pool Replenishment (2020-2050):** This projected future phase highlights a shift

Table 4. Dominant Parameters Impacting Carbon Emissions in a Building
Source: Author

Category	Denotation	Dominant Parameters	Description	Impact on Carbon Emissions	Source
Building Design Parameters (D)	D1	Building Location and Climate	The local climate and site conditions affect energy demands for heating, cooling and daylighting.	Buildings in hotter climates typically have higher cooling loads, while those in colder regions have higher heating demands, influencing operational carbon emissions.	Bazazzadeh et al. (2021)
	D2	Orientation	Affects solar gain and energy efficiency.	Significant impact on operational energy use.	Dousoky et al. (2011)
	D3	Window-to-Wall Ratio (WWR)	Balances daylight and thermal performance; optimal ranges vary with climate.	Influences heating/cooling loads.	Alwetaishi & Benjeddou (2021)
	D4	Insulation Thickness	Enhances thermal performance, reducing heating and cooling demands.	Critical for minimising operational emissions.	Voll & Seinre (2014)
	D5	Building Geometry	Simplified geometric models can predict carbon impact early in design.	Effects embodied carbon calculations.	Giordano et al. (2021)
Construction Parameters (C)	C1	Construction Practices (waste management)	Efficient practices minimise waste and energy use during construction.	Reduces emissions during the construction phase.	Nzima (2022)
	C2	Prefabrication Rate	Higher prefabrication rates can reduce onsite waste and improve efficiency.	Potentially lowers construction stage emissions.	Han et al. (2022)
	C3	Transportation of Materials	The distance materials are transported affects overall emissions.	Longer distances increase carbon footprint.	Han et al. (2020)
Operation Parameters (O)	O1	Renewable Energy Integration	Integrating renewable energy reduces reliance on grid electricity generated from fossil fuels, lowering operational carbon emissions.	The use of renewable energy sources like solar panels or geothermal systems can offset energy consumption from fossil fuels.	Sher et al. (2021)
	O2	Energy Systems Efficiency (HVAC, lighting)	Efficient systems reduce operational energy consumption significantly.	Major contributor to operational emissions (60-85%).	Oluseyi et al. (2020), Genco et el. (2018)
	O3	Occupant Behavior	User habits influence energy consumption patterns; education can lead to reductions in use.	Directly affects operational energy demand.	Deng & Chen (2019)
	O4	Maintenance Practices	Regular maintenance ensures systems operate efficiently over time, minimising waste.	Helps sustain low operational emissions over time.	Amaral et al. (2020)
Material Criteria (M)	M1	Embodied Carbon Assessment	Evaluates total carbon footprint from material extraction to disposal; essential for life cycle analysis.	Accounts for about 20% of total lifecycle emissions Key factor in life cycle analysis; affects overall carbon footprint.	Mohebbi et al. (2021)
	M2	Building Materials choice	The type and quantity of materials used in construction have a direct impact on embodied carbon.	Materials like steel, concrete and aluminum have high carbon footprints due to energy-intensive manufacturing processes. Selecting low-carbon alternatives like sustainably harvested wood, recycled materials, or bio-based products can significantly reduce embodied carbon.	Reddy (2009)
	M3	Recyclability and Durability	Contributes to lower lifecycle emissions overall.	Durable and recyclable materials reduce end-of-life emissions and promote sustainability principles.	Dodoo (2019)

towards bio-based construction materials such as glulam, bamboo and Cross-Laminated Timber (CLT). These materials, derived from plants (biological sinks), sequester atmospheric carbon during their growth. By incorporating them into the built environment, buildings themselves can become significant, long-term man-made carbon sinks. This strategy, as visualised by the greener city and growing terrestrial pool, offers a pathway to draw down atmospheric carbon and replenish terrestrial stores, contributing to climate change mitigation efforts.

6.1.1 Biological Carbon Sinks

Natural systems like forests, oceans and soil are vital to combating climate change (Pandey, 2002). These biological carbon sinks absorb and store carbon dioxide (CO_2) from the atmosphere, playing a crucial role in regulating the global carbon cycle. Protecting and enhancing these natural resources is essential for creating a sustainable future for our planet.

- **Forests:** Forests are one of the most significant biological carbon sinks. Trees and other vegetation absorb CO_2 during photosynthesis and store it in their biomass.
- **Wetlands:** Wetlands, including marshes and swamps, can absorb carbon in their soils, as well as in the vegetation that grows in these areas.
- **Oceans:** The world's oceans act as a massive carbon sink. Phytoplankton and marine ecosystems absorb and store carbon and the deep ocean can store dissolved CO_2.

6.1.2 Geological Carbon Sinks

Geological formations beneath the surface, such as saline aquifers and depleted oil and gas reservoirs, can be utilised as secure storage sites for captured carbon dioxide (CO_2). This process, known as (CCS) carbon capture and storage or carbon sequestration, involves storage for the long-term of CO_2 deep underground in a safe, secure manner.

6.2 Mineralisation

Certain minerals, such as olivine, possess the ability to react with CO_2, resulting in the formation of stable carbonates. This process effectively locks away carbon from the atmosphere for extended periods, contributing to long-term sequestration.

The release of substantial amounts of CO_2 into the atmosphere is primarily driven by human activities. These activities encompass deforestation, alterations in land utilisation patterns and the combustion of fossil fuels, each of which contributes to the accumulation of CO_2 in the air. Efforts to combat climate change often include enhancing existing carbon sinks and creating new ones, like reforestation and afforestation projects, which involve planting trees or restoring forests to capture and store more carbon. The preservation and growth of carbon sinks play a crucial role in international climate change mitigation efforts and endeavours to lower atmospheric CO_2 levels.

7. Conclusion

This research investigated the carbon footprint of residential buildings in India's composite climate zone. The study employed a combination of field surveys, data collection and sample building computer-based simulations to assess the impact of building design, materials, energy consumption and occupant behaviour on carbon emissions.

The findings highlight that various factors significantly influence the carbon loads of residential buildings in Greater Noida. These include building design elements like orientation and insulation, the selection of construction materials and the usage of renewable energy. Additionally, occupant behaviour and lifestyle choices regarding electricity consumption play a vital role in finding a building's environmental impact.

This research offers valuable insights for architects, builders, policymakers and residents of Greater Noida and similar composite climate zones worldwide. By implementing the suggested strategies, such as promoting energy-efficient building practices, utilising renewable energy sources and fostering sustainable occupant behaviour, significant reductions in carbon emissions from residential buildings can be achieved. This will surely contribute to creating a better low-carbon built environment and mitigating the effects of climate change.

References

1. Alwetaishi, M., & Benjeddou, O. (2021). Impact of window to wall ratio on energy loads in hot regions: A study of building energy performance. *Energies*, *14*(4), 1080. https://doi.org/10.3390/en14041080
2. Amaral, R. E. C., Brito, J., Buckman, M., Drake, E. D., Ilatova, E., Rice, P. E., & Abraham, Y. S. (2020). Waste management and operational energy for sustainable buildings: A review. *Sustainability*, *12*(13), 5337. https://doi.org/10.3390/su12135337

3. Ang, Y. Q., Berzolla, Z. M., Letellier-Duchesne, S., & Ürge-Vorsatz, D. (2023). Carbon reduction technology pathways for existing buildings in eight cities. *Nature Communications*, *14*(1), 1689. https://doi.org/10.1038/s41467-023-37131-6
4. Batra, G. (2023). Renewable energy economics: Achieving harmony between environmental protection and economic goals. *Social Science Chronicle*, *2*(2), 1-32.
5. Bazazzadeh, H., Nadolny, A., & Safaei, S. S. H. (2021). Climate change and building energy consumption: A review of the impact of weather parameters influenced by climate change on household heating and cooling demands of buildings. *European Journal of Sustainable Development*, *10*(2), 1–12. https://doi.org/10.14207/ejsd.2021.v10n2p1
6. Chaturvedi, P. K., Kumar, N., & Lamba, R. (2024). Finding the gaps in design strategies and technological advancements for net-zero energy buildings development in India. *Energy & Environment*. Advance online publication. https://doi.org/10.1177/0958305X241256039
7, Chen, Z. M., & Chen, G. Q. (2011). An overview of energy consumption of the globalized world economy. *Energy Policy*, *39*(10), 5920-5928.
8. Deng, Z., & Chen, Q. (2019). Impact of occupant behavior on energy use of HVAC system in offices. *E3S Web of Conferences*, *111*, 04055. https://doi.org/10.1051/e3sconf/201911104055
9. Ding, Z., Jiang, X., Liu, Z., Long, R., Xu, Z., & Cao, Q. (2018). Factors affecting low-carbon consumption behavior of urban residents: A comprehensive review. *Resources, Conservation and Recycling*, *132*, 3-15.
10. Dodoo, A. (2019). Lifecycle impacts of structural frame materials for multi-storey building systems. *Journal of Sustainable Architecture and Civil Engineering*, *24*(1), 17–28. https://doi.org/10.5755/j01.sace.24.1.23229
11. Dousoky, G. M., El-Sayed, A. H. M., & Shoyama, M. (2011). Improved orientation strategy for energy-efficiency in photovoltaic panels. *Journal of Power Electronics*, *11*(3), 335–341. https://doi.org/10.6113/jpe.2011.11.3.335
12. Gadre, R., & Anandarajah, G. (2019). Assessing the evolution of India's power sector to 2050 under different CO2 emissions rights allocation schemes. *Energy for Sustainable Development*, *50*, 126-138.
13. Geelani, S. M., Geelani, S. H., Bhat, S. J. A., Haq, S., & Ahmad, N. (2012). Green building development for sustainable environment with special reference to India. *International Journal of Environment and Bioenergy*, *4*(2), 86-100.
14. Genco, A., Viggiano, A., & Magi, V. (2018). How to enhance the energy efficiency of HVAC systems? *Mathematical Modelling and Engineering Problems*, *5*(3), 153–160. https://doi.org/10.18280/mmep.050304
15. Giordano, R., Gallina, F., & Quaglio, B. (2021). Analysis and assessment of the building life cycle. Indicators and tools for the early design stage. *Sustainability*, *13*(11), 6467. https://doi.org/10.3390/su13116467
16. Han, Q., Chang, J., Liu, G., & Zhang, H. (2022). The carbon emission assessment of a building with different prefabrication rates in the construction stage. *International Journal of Environmental Research and Public Health*, *19*(4), 2366. https://doi.org/10.3390/ijerph19042366
17. Han, S., Na, S., & NamGi, L. (2020). Evaluation of road transport pollutant emissions from transporting building materials to the construction site by replacing old vehicles. *International Journal of Environmental Research and Public Health*, *17*(24), 9316. https://doi.org/10.3390/ijerph17249316
18. Huang, L., Krigsvoll, G., Johansen, F., Liu, Y., & Zhang, X. (2018). Carbon emissions of global construction sector. *Renewable and Sustainable Energy Reviews*, *81*, 1906-1916.
19. Ibn-Mohammed, T., Greenough, R., Taylor, S., Ozawa-Meida, L., & Acquaye, A. (2013). Operational vs. embodied emissions in buildings—A review of current trends. *Energy and Buildings*, *66*, 232-245.
20. Jain, A. K. (2023). *Climate resilient, green and low carbon built environment*. Springer Nature.
21. Marimuthu K. N. (2012). Green business in India: Opportunities and challenges. *Asian Journal of Research in Business Economics and Management*, *2*(10), 215-227.
22. Mohebbi, G., Bahadori-Jahromi, A., Ferri, M., & Mylona, A. (2021). The role of embodied carbon databases in the accuracy of life cycle assessment (LCA) calculations for the embodied carbon of buildings. *Sustainability*, *13*(14), 7988. https://doi.org/10.3390/su13147988
23. Mostafavi, F., Tahsildoost, M., & Zomorodian, Z. (2021). Energy efficiency and carbon emission in high-rise buildings: A review (2005-2020). *Building and Environment*, *206*, 108329.
24. Nejat, P., Jomehzadeh, F., Taheri, M. M., Gohari, M., & Majid, M. Z. A. (2015). A global review of energy consumption, CO2 emissions and policy in the residential sector (with an overview of the top ten CO2 emitting countries). *Renewable and Sustainable Energy Reviews*, *43*, 843-862.
25. Nzima, L. (2022). Construction waste management practices in the construction industry. *Journal of Natural and Applied Sciences*, *5*(1), 39–55. https://doi.org/10.53974/unza.jonas.5.1.713
26. Oluseyi, P. O., Somefun, T. E., Babatunde, O. M., Akinbulire, T. O., Babayomi, O., Isaac, S. A., & Babatunde, D. E. (2020). Evaluation of energy-efficiency in lighting systems for public buildings. *International Journal of Energy Economics and Policy*, *10*(6), 435–439. https://doi.org/10.32479/ijeep.9905
27. Omer, A. M. (2008). Energy, environment, and sustainable development. *Renewable and Sustainable Energy Reviews*, *12*(9), 2265-2300.

28. Omer, A. M. (2014). Energy efficiency improvement utilising high technology: The path forward for renewable energy use in industry, buildings and sustainable development. *Blue Biotechnology Journal*, *3*(2), 183.
29. Pandey, D. N. (2002). Global climate change and carbon management in multifunctional forests. *Current Science*, *83*(5), 593-602.
30. Reddy, B. V. V. (2009). Sustainable materials for low carbon buildings. *The International Journal of Low Carbon Technologies*, *4*(3), 175–181. https://doi.org/10.1093/ijlct/ctp025
31. Sher, F., Curnick, O., & Azizan, M. T. (2021). Sustainable conversion of renewable energy sources. *Sustainability*, *13*(5), 2940. https://doi.org/10.3390/su13052940
32. Singh, A. K., & Prasad, A. (2000). Case study Tata Energy Research Institute (TERI). *Vision*, *4*(1), 52-64.
33. Ürge-Vorsatz, D., Petrichenko, K., Staniec, M., & Eom, J. (2013). Energy use in buildings in a long-term perspective. *Current Opinion in Environmental Sustainability*, *5*(2), 141-151.
34. Voll, H., & Seinre, E. (2014). A method of optimizing fenestration design for daylighting to reduce heating and cooling loads in offices. *Journal of Civil Engineering and Management*, *20*(5), 714–723. https://doi.org/10.3846/13923730.2013.801920
35. Wani, K. K., & Mushtaq, J. (2018). Green buildings-a review. *International Journal of Advance Research in Science and Engineering*, *7*, 1957-1966.

Ar. Akshay Sanyal (A29036) is a research scholar from the Department of Architecture and Regional Planning at Gautam Buddha University, Greater Noida (U.P.). He earned his postgraduate degree in Sustainable Architecture from GITAM University, Visakhapatnam, and his Bachelor of Architecture degree from RTMNU, Nagpur University, establishing a robust background in architectural design and sustainable development.
Email: akshaysanyal@gmail.com

Dr. Nirmita Mehrotra (A11636) is presently Head at the Department of Urban and Regional Planning, and Former and founder Head, Deptt of Architecture, School of Engineering, Gautam Buddha University, Greater Noida (U.P.). As an academician, practitioner and urban scientist, she has won many prestigious awards, including the Outstanding Academician Award 2025 and the Aarika Pinkprint Pioneer Women Architect 2024 and the National Award (ISTEGSITS, 1998) for her research work. She is a member of reputed professional bodies lFellow of Institute of Town Planners India (ITPI) and Indian Building Congress, India Fire and Safety Association of India and Indian Institute of Architects, EC Member UP Chapter (2023–2025). Her expertise encompasses disaster resilience and climate change adaptation, Green buildings, Accessible cities, urban informatics and complexities of urban systems.
Email: nirmita2006@gmail.com

STUDENT WORK

Urban Ecology Frameworks

A Systematic Exploration of the Literature

By Anshrah Kidwai, Dr. Zeeshan Ibrar and Dr. Nisar Khan

1. Introduction

The impact of human activity on the Earth's environmental systems is now so dominant that it is recognised as a new geological age: the Anthropocene, or human-dominated geological epoch (Nijhuis & Jauslin, 2015). More than half of the world's population resided in cities in 2015 and by 2050, two-thirds of all people are predicted to do so (Ahern et al., 2014; Wu, 2014). In city like Delhi, where the population is moving from rural to urban regions within a comparatively short period of time, this trend has been even more pronounced, profoundly affecting urban ecology (Steiner, 2014). The rapid expansion of cities has altered ecosystems, resulting in biodiversity loss, pollution and increased resource consumption. Simultaneously, urban environments create new ecological niches and offer opportunities for innovative sustainability strategies

Cities are the source of 80% of the greenhouse gas emissions linked to climate change. The design of urban areas with more impermeable surfaces and less vegetation exacerbates the effects of urban heat islands, which worsen heat waves that negatively affect public health (Ahern et al., 2014). From an urban ecology perspective, cities physically alter land use patterns, fragment and degrade habitats, introduce exotic species and alter natural hydrological, energy flow and nutrient recycling patterns, all of which pose a threat to species diversity and ecosystems (Ahern et al., 2014). These changes disrupt ecosystems, reducing the ability of native species to thrive and increase the dominance of urban-adapted species.

The idea that cities and urban environments represent a special kind of integrated human nature is becoming more widely accepted (Steiner, 2014; Wu, 2014). It is possible to apply systems thinking to city planning by considering cities as socio-ecological systems. As a result, urban ecology, the study of ecosystems within urban environments, has emerged as a critical field to understand how natural and social systems interact within cities. It investigates ecosystem services which are closely linked to patterns of urban development (Alberti, 2005).

To address the intricate interactions between human activities and ecological processes in urban areas, various frameworks have been developed. These frameworks offer distinct conceptual approaches to studying urban ecosystems, analysing patterns, flows and feedback loops. Given the growing importance of building resilient, sustainable and equitable cities, understanding and synthesising these frameworks is essential.

This systematic literature review (SLR) explores existing frameworks in urban ecology, focusing on their conceptual underpinnings, applications and evolution. The objective is to synthesise the literature to identify key frameworks, trends and research gaps that shape urban ecological research and practice.

2. Methodology

The systematic search and analysis of relevant studies is more transparent than traditional narrative literature reviews. It is also more likely to produce a broader range of articles that allow for the mapping of specific trends or theoretical directions as well as the ability to identify gaps and areas of uncertainty (O'Brien & Guckin, 2016). Only pertinent studies can be included in the review process since specific inclusion and exclusion criteria are used. It aims to provide a transparent and unbiased summary of the urban ecological frameworks and assess emerging

ecological paradigm in this area. This can facilitate collaboration among researchers and practitioners from diverse disciplines, leading to more holistic urban solutions. Study followed several best practice models for conducting a systematic literature review (SLR) and was carried out through five distinct stages - problem description and scope, search string formulation, literature search, results and analysis followed by discussion and conclusion (Cooper, 2017; Xavier et al., 2017).

2.1 Problem, Definition and Scope

This SLR seeks to identify and map the various frameworks used in urban ecology and understanding the key concepts, models and theories that have been developed to study the interactions between urban environments and ecological processes. Scope of work includes detailed analysis of frameworks in terms of their definitions, methodologies and applications in urban ecology and identify their strengths, limitations and areas of overlap.

2.2 Formulation of Search String

The second stage was determining the more precise search term associated with the stated objectives. Using the keywords, a preliminary database scan of the current databases was conducted to find potential papers related to the topics of urban ecology, urban ecological frameworks, urban green infrastructure and urban continuity. The resulting papers, which are organised in Table 1, were utilised to identify keywords and related terms that are often used in the literature.

2.3 Literature Search

After developing, the search string was tested in several renowned databases and following were chosen for SLR: SCOPUS, ProQuest, ScienceDirect, SpringerLink and Web of Science. After exporting references into Zotero and eliminating duplicates, 150 original articles were found. To find papers that contained the chosen keywords, titles and abstracts were scanned. To aid in filtering and additional analysis, the resulting references which included authors, year of publication, title and abstract were then exported to an Excel spreadsheet. After examining the titles and abstracts of these papers, it was determined that only 86 of them were pertinent to the study. Few articles were eliminated since it was determined that they were included in the grey literature. Ultimately, the systematic literature review comprised just 46 papers and its conclusions are expounded upon. A flow diagram (Figure 1) based on the PRISMA 2009 Flow Diagram (Moher et al., 2009) shows the literature search process of article selection for the SLR.

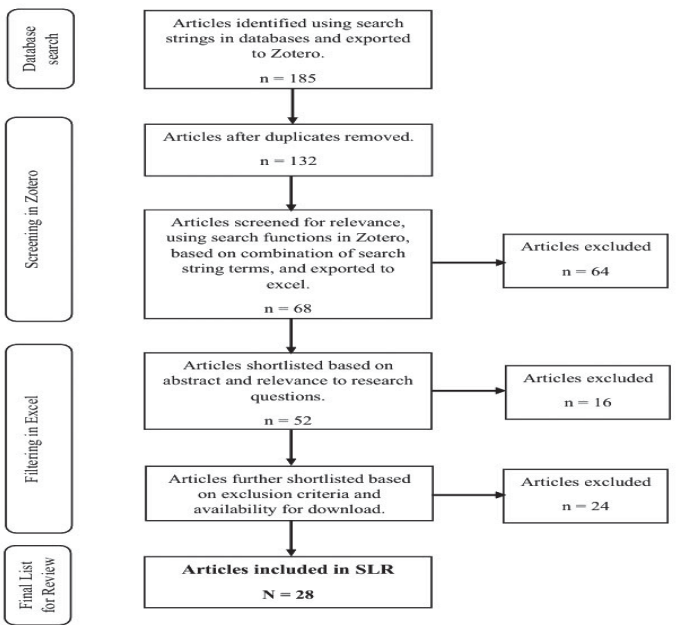


Figure 1. Process of selecting articles for the Systematic Literature Review from 2000 to 2024 following an initial literature search (based on the PRISMA flow diagram)
Source: Author

Table 1: Keywords and its associated terms
Source: Compiled by author

Keywords	Associated Terms
Ecology	Ecosystem services, population dynamics, ecosystems, landscape ecology, ecological resilience, biodiversity, nature, conservation, wildlife
Urban	Urbanisation, urban infrastructure, urban sprawl, gentrification, urban density
Systems	Systems thinking, systems approach, synthesis, dynamics, thresholds, flows, metabolism, uncertainty, non-linear, circular, holism, integration, trans-disciplinarity, resilience
Frameworks	Conceptual model, ttheoretical framework, methodological framework
Infrastructure	Built environment, green infrastructure, blue infrastructure, ecological infrastructure, integrated infrastructure

3. Results and Discussions

This section presents and analyses the key findings of the systematic literature review, providing insights into the most frequently used urban ecology frameworks, their evolution over time, their applications in urban planning and governance and the limitations and gaps identified in the literature.

3.1 Reviewed Articles

All the articles reviewed were written in the last twenty years, with the majority (82%) written in the last eight years, providing some evidence that the Urban Ecology frameworks are gaining increasing relevance and evolving rapidly in response to emerging environmental and social challenges. This trend suggests that researchers and practitioners are placing greater emphasis on understanding complex urban systems, driven by growing concerns about climate change, urbanisation, biodiversity loss and environmental justice (McPhearson et al., 2016). As shown in Figure 2, there is a clear upward trend in the number of articles published in recent years, particularly in 2016 and 2024, indicating a surge in academic interest and research output in this field. The recent surge in publications indicates a shift toward integrating ecological principles with urban planning and governance, as cities seek to become more sustainable, resilient and equitable.

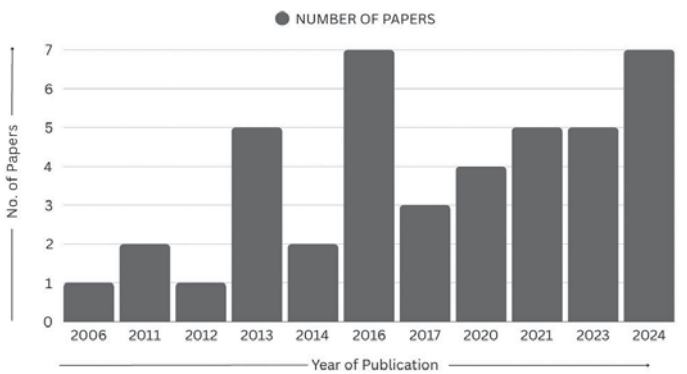


Figure 2: Number of articles by year of publication in the SLR
Source: Author

3.2 Identified frameworks in Urban Ecology

The review identified several core frameworks used to understand urban socio-ecological dynamics. These are discussed in the following sections.

3.2.1 Biophilic Cities Framework

Biophilic cities are cities that provide close and daily contact with nature, nearby nature, but also seek to foster an awareness of and caring for this nature (Beatley & Newman, 2013). A fascinating idea for the layout and construction of cities in the future is the idea of "biophilic cities," also known as "biophilic urbanism." It builds on the essential insight of "biophilia"- that humans are drawn to nature and that humans have an innate connection or affiliation with the natural world (Beatley, 2017). Adopting biophilic elements in architecture design and urbanism is believed to have a direct impact on people's health, like reducing stress, emotional well-being, boosting creativity, healing effects and increasing productivity (Russo & Cirella, 2017). Table 2 illustrates how biophilic elements can be embedded at three key urban design scales: building, block and street. This framework offers a holistic approach to urban sustainability, fostering healthier and more resilient cities.

Table 2: Biophilic city design elements across scales
Source: Modified from Beatley, 2017

Scales	Biophlic Design Elements
Building	Green rooftops
	Sky gardens and green atria
	Rooftop garden
	Green walls
	Day-lit interior spaces
	Green courtyards
Block	Clustered housing around green areas
	Native species yards and spaces
	Green streets
	Urban trees
Street	Low impact development (LID)
	Vegetated swales and skinny streets
	Edible landscaping
	High degree of permeability
	Stream daylighting, stream restoration

3.2.2 Blue Green Infrastructure (BGI)

BGI is characterised as a network of interconnected natural and artificial landscape elements, such as open green spaces and water bodies that serve a variety of purposes. BGI, also known as nature-based solutions (NBS) or green infrastructure (GI), is slightly different in that it is particularly made to turn "blue" (or "bluer") during rainy events in order to control stormwater and lower the danger of flooding. Healthy urban riparian zones are also recognised as BGI resources that offer chances for recreation and environmental improvement and serve as an ecological network linking (physically, visually and ecologically) BGI in urban areas with surrounding natural areas and blue green space (O'Donnell et al., 2021). Blue Green Assets include green roofs, green walls, swales, rain gardens, street trees, ponds,

urban wetlands, restored watercourses, reconnected floodplains, re-naturalised rivers and de-culverted rivers.

Case Study of Melbourne, Australia (Almaaitah et al., 2021)

The case of Melbourne, Australia focuses on using Blue Green Infrastructure (BGI) for urban heat island (UHI) mitigation. The aspects considered are -

i. Climate-Service Oriented Models: The TARGET model was applied to simulate the cooling potential of tree cover and irrigated grass at the street level.

ii. Temperature Biases: Simulations revealed that urban areas experience warmer temperatures than rural zones, indicating how BGI can address uneven heat distribution in cities.

iii. Challenges and Trade-offs: Due to drought conditions exacerbated by climate change, Melbourne faces the challenge of balancing water conservation with the need for irrigation to reduce heat. The study suggests using harvested rainwater and locally treated greywater for irrigation to mitigate UHI while conserving water resources.

The Blue-Green Infrastructure framework integrates natural water management and green spaces to enhance urban resilience, improve water quality and provide ecological benefits. It promotes sustainable urban development by balancing built environments with nature.

3.2.3 Continuum of Urbanity

The framework maps urbanity not just as physical built-up areas but as a mix of livelihoods, lifestyles and connectivity. It reveals that urban characteristics extend beyond traditional city boundaries, challenging the conventional urban-rural gradient theory (Zhaxi et al., 2024). It views urbanisation not just as a physical transformation but as a process-based definition. This approach integrates social and ecological factors, providing a more holistic understanding of urban landscapes beyond geographic boundaries (Hahs, 2016). Table 3 outlines four key dimensions of the urban continuum - livelihood, lifestyle, connectivity and attributes of place, highlighting how urban influences extend into rural areas. It emphasises that urbanisation is a multifaceted process shaped by economic, social, technological and environmental factors.

Case Study of Melbourne, Australia (Pickett & Zhou, 2015)

Beijing exemplifies the continuum of urbanity with its rapid transformation of rural villages into urbanised zones, creating a hybrid landscape of traditional and modern systems. The aspects are -

i. Urban Villages: Rural settlements engulfed by urban expansion retain rural structures amidst urban settings.

ii. Infrastructure: High-speed rail, highways and digital networks connect Beijing to neighbouring regions and globally.

iii. Livelihood Shifts: Economic activities transition from agriculture to urban service and market participation.

Table 3: Dimensions of Urban Continuum
Source: Pickett & Zhou, 2015

Dimensions of Urban Continuum	
Livelihood	The economic activities people engage in, ranging from rural agriculture to urban market-based economies. The shift in livelihoods reflects the transition and integration between urban and rural settings.
Lifestyle	Includes social identity, consumption patterns and cultural behaviours that may spread beyond city boundaries and influence rural areas, showing that urban lifestyles are no longer confined to urban centres.
Connectivity	The physical and technological infrastructure that links urban and rural places, enabling telecommunication, transportation and the exchange of resources and information across great distances. This connectivity challenges the traditional, localised view of cities and rural areas.
Attributes of Place	The biophysical and social characteristics of locations, including the natural environment and cultural significance, which are influenced by both global and local processes.

Beijing's development fosters economic integration and global connectivity while raising challenges like social displacement and environmental strain. It highlights the balance needed between urban expansion and cultural-ecological sustainability. This continuum approach provides a comprehensive and integrated model for understanding urbanisation's diverse forms and dynamics across the globe.

3.2.4 Metacity

The term "Metacity" refers to a variety of urban arrangements with unique ecological and social characteristics, not just big urban agglomerations. It includes new forms of urbanisation shaped by digital technologies, creating a "virtual meta-infrastructure" that is present in all cities today (McGrath & Pickett, 2011).

i. Socio- Ecological Dynamics: The metacity framework emphasises that urban systems are composed of interconnected patches, which relate to metapopulation and metacommunity theories in ecology. These patches interact dynamically, adapting to changes in resources, social processes and ecological conditions. It highlights how cities function as "systems of systems," combining biophysical and social components, making it possible to understand the complexity of cities through their socio-ecological processes (McGrath & Pickett, 2011).

ii. Urban Meta-Mosaic: A central concept is the "urban meta-mosaic," a hierarchical structure of urban landscapes that integrates ecological, social and institutional elements. As illustrated in Figure 3, this framework consists of three interrelated components - the process mosaic (representing flows such as energy or nutrients), the choice mosaic (capturing human decisions like planning and policy) and the outcome mosaic (reflecting measurable impacts such as biodiversity or equity outcomes). This meta-mosaic includes landscapes of process (e.g., nutrient flux), choice (e.g., policy and design) and outcome (e.g., biodiversity and justice). The urban meta-mosaic approach offers a way to manage spatial heterogeneity and connectivity across cities, suburbs and exurban areas, linking local interventions to regional and global ecological processes.

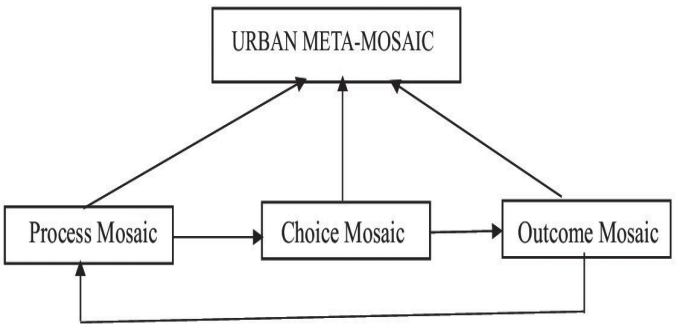


Figure 3. Three Components of Meta mosaic
Source: Pickett et al., 2013

Case Study of New York (Pickett et al., 2013)

New York's urban ecosystem has been shaped by a combination of natural elements (waterways, parks, trees) and human infrastructure. The city's network of parks, especially large green areas like Central Park, integrates ecology into the urban environment.

i. Social and Environmental Mosaics: The city consists of varied social patches defined by economic disparities, cultural diversity and land-use differences. Recent efforts focus on fostering environmental stewardship and community resilience, particularly in waterfront areas vulnerable to climate change.

ii. Post-Industrial Adaptation: As part of its adaptive strategies, New York has introduced projects that integrate soft ecological approaches, such as green roofs and bioswales, with hard urban infrastructure to mitigate issues like urban flooding and the urban heat island effect.

iii. Process Mosaics: The city manages complex flows, including demographic shifts (with international migration boosting population), water management systems and transport networks.

The metacity framework conceptualises cities as dynamic systems of interconnected ecological, social and spatial mosaics. It integrates patch dynamics, ecological resilience and urban design to address sustainability and adaptive challenges in both large and smaller urban areas.

3.2.5 Patch Dynamics

Patch dynamics refers to a conceptual approach that studies the structure and function of ecosystems by viewing them as mosaics of discrete, interacting patches. In the context of urban ecology, it emphasises understanding spatiotemporal changes and interactions within these patches. The hierarchical patch dynamics paradigm (HPDP) is used to interpret

Table 4: Urban Growth Modes
Source: Li et al., 2013

Term	Meaning
Infilling	This occurs when new urban development happens within an area already largely surrounded by existing urban land. It contributes to increased density by filling the gaps within built-up areas, making urban areas more compact.
Edge-expansion	This involves new development occurring at the periphery or the edges of existing urban areas. This type of growth gradually extends the boundaries of urban regions outward in a contiguous manner.
Leapfrogging	Also known as "outlying expansion," this mode occurs when new urban development emerges in locations not directly adjacent to existing urban areas. Leapfrogging leads to isolated patches of urbanisation that are separated by non-urban land, contributing to a more fragmented landscape.

urban landscape changes, focusing on the multi-scaled, interconnected nature of urban systems. This approach helps analyse how urban growth modes like infilling, edge-expansion and leapfrogging affect landscape patterns and ecological processes As illustrated in Table 4, these growth modes represent distinct spatial development patterns, ranging from compact internal densification (infilling), to outward contiguous spread (edge-expansion) and fragmented development beyond existing urban areas (leapfrogging) each with different implications for urban form and ecological sustainability (Li et al., 2013).

Case Study: Patch Dynamics in Forest Ecosystems (Xu & Cornelissen, 2023)

Patch dynamics is a framework that views ecological systems as mosaics of patches, each undergoing dynamic changes due to natural and anthropogenic factors. It highlights how local changes interact to shape broader ecological patterns and processes. A notable application of this concept is seen in forest ecosystems, where disturbances such as tree falls, fires and human activities create a patchy landscape. The aspects are -

i. Dynamic Mosaic: Forests are composed of patches of varying sizes, ages and successional stages resulting from disturbances like canopy gaps caused by fallen trees.

ii. Scale Dependency: Processes at smaller scales (e.g., seed dispersal in a gap) influence and are influenced by larger-scale phenomena (e.g., forest structure and nutrient cycling).

iii. Hierarchical Structure: The forest ecosystem integrates local patch dynamics into broader-scale stability, exemplified by concepts like the "shifting mosaic steady state."

This patch dynamics perspective provides insights into:

i. Resilience and Adaptation: Ecosystems' ability to recover and adapt to disturbances.

ii. Conservation Strategies: Managing forest mosaics for biodiversity, carbon sequestration and ecosystem services.

iii. Sustainability: Understanding patch-level processes to inform sustainable forestry practices.

The patch dynamics framework helps interpret urbanisation not just as isolated developments but as interconnected processes with shifting dominance of growth modes.

3.2.6 Urban Resilience

Resilience in urban ecology involves safeguarding and enhancing natural systems like forests, wetlands and rivers to ensure they continue to provide services such as flood mitigation, air purification and biodiversity support (Collier et al., 2014). This framework focuses on enabling cities to adapt, transform and thrive despite challenges posed by climate change and other stressors. It integrates ecological, social and infrastructural systems to support sustainable urban development (Tyler & Moench, 2012).

Case Study- Hurricane Sandy - New York and New Jersey Impacts

Hurricane Sandy (October 2012) caused $70 billion in damages, with 159 fatalities. Failures were flood damaged transit, water and sewer systems, power outages disrupted hospitals and homes. Poor land-use planning and inadequate emergency systems worsened impacts.

Solutions that needed to get incorporated were improve land-use policies to reduce coastal risks, enhance community education, communication and preparedness, focus on governance reforms and flexible and cost-effective responses. As shown in Figure 4, the event exposed systemic vulnerabilities across urban systems, such as infrastructure, governance, social capital and natural environment while emphasising the importance of resilience principles like redundancy, flexibility, responsiveness and the capacity to learn. Thus, resilience required better planning, governance and community adaptation to mitigate future risks (Collier et al., 2014).

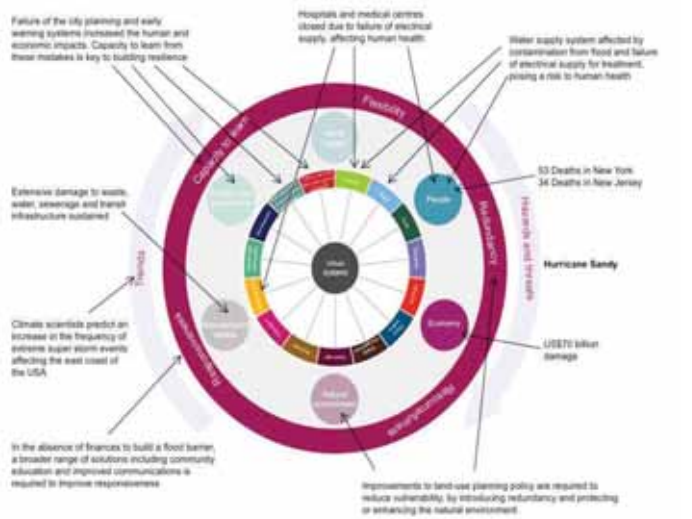


Figure 4: Hurricane Sandy - system failures, impacts and ways to build resilience
Source: Collier et al., 2014

4. Conclusion

The rapid pace of urbanisation in the Anthropocene has deeply altered ecosystems, creating challenges that demand innovative, interdisciplinary approaches to urban planning and development. This study reviewed and synthesised six critical frameworks -Biophilic Cities, Blue-Green Infrastructure, Continuum of Urbanity, Metacity, Patch Dynamics and Urban Resilience that provide valuable insights into addressing the complex interplay between urban growth and ecological sustainability. Together, these frameworks highlight diverse methodologies and concepts aimed at creating cities that are not only functional but also ecologically harmonious and resilient.

The Biophilic Cities framework emphasises the integration of nature into urban environments to improve mental health, reduce stress and enhance ecological vitality. It advocates for green roofs, urban forests and nature-centered design as essential components of future cities.

Blue-Green Infrastructure combines natural elements with engineered solutions, focusing on managing water resources, reducing urban heat islands and increasing biodiversity through multifunctional green and blue spaces.

The Continuum of Urbanity challenges traditional distinctions between urban and rural areas, highlighting the dynamic socio-ecological and economic interactions that transcend geographical boundaries.

The Metacity framework provides a vision of cities as adaptive and interconnected systems, composed of ecological, social and digital networks that enable urban environments to respond flexibly to changing needs.

Patch Dynamics focuses on the spatial and temporal variability within urban landscapes, offering a detailed understanding of growth modes such as infilling, edge expansion and leapfrogging and their implications for ecological processes.

Finally, Urban Resilience emphasises the development of systems that can adapt and thrive amid environmental and social challenges, incorporating strategies to mitigate climate impacts, enhance infrastructure and support community well-being.

These frameworks collectively underscore the importance of adaptive and integrated approaches in urban planning. They highlight the need for interdisciplinary collaboration, locally contextualised solutions and the bridging of theory and practice to effectively address the challenges posed by urbanisation. Despite their transformative potential, many of these frameworks remain underexplored in diverse global contexts, limiting their real-world application.

Future research must focus on scaling these frameworks across varied socio-cultural and environmental settings, fostering innovation and developing policies that align urban growth with ecological principles. By doing so, urban ecology can reshape cities into thriving ecosystems, supporting biodiversity, enhancing human well-being and

building resilience to climate change. Embracing these frameworks offers a pathway toward more sustainable, equitable and resilient urban futures, where the intricate balance between human and natural systems is maintained and celebrated.

Reference

1. Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. Landscape and Urban Planning, 125, 254–259. https://doi.org/10.1016/j.landurbplan.2014.01.020
2. Alberti, M. (2005). The effects of urban patterns on ecosystem function. International Regional Science Review, 28(2), 168–192. https://doi.org/10.1177/0160017605275160
3. Almaaitah, T., Appleby, M., Rosenblat, H., Drake, J., & Joksimovic, D. (2021). The potential of Blue-Green infrastructure as a climate change adaptation strategy: A systematic literature review. Blue-Green Systems, 3(1), 223–248. https://doi.org/10.2166/bgs.2021.016
4. Beatley, T. (2017). Biophilic cities and healthy societies. Urban Planning, 2(4), 1–4. https://doi.org/10.17645/up.v2i4.1054
5. Beatley, T., & Newman, P. (2013). Biophilic cities are sustainable, resilient cities. Sustainability (Switzerland), 5(8), 3328–3345. https://doi.org/10.3390/su5083328
6. Collier, F., Hambling, J., Kernaghan, S., Kovacevic, B., Miller, R., Pérez, A. P., Richardson, E., & Macmillan, S. (2014). Tomorrow's cities: A framework to assess urban resilience. Proceedings of the Institution of Civil Engineers: Urban Design and Planning, 167(2), 79–91. https://doi.org/10.1680/udap.13.00019
7. Cooper, H. M. (2017). Research Synthesis and Meta-Analysis: A Step-by-Step Approach. Sage Publications.
8. Hahs, A. K. (2016). Urban megaregions and the continuum of urbanity—embracing new frameworks or extending the old? Ecosystem Health and Sustainability, 2(1), 1–2. https://doi.org/10.1002/ehs2.1201
9. Li, C., Li, J., & Wu, J. (2013). Quantifying the speed, growth modes, and landscape pattern changes of urbanization: a hierarchical patch dynamics approach. Landscape Ecology, 28, 1875–1888.
10. McGrath, B., & Pickett, S. T. A. (2011). The Metacity: A Conceptual Framework for Integrating Ecology and Urban Design. Challenges, 2(4), 55–72. https://doi.org/10.3390/challe2040055
11. McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J., & Qureshi, S. (2016). Advancing Urban Ecology toward a Science of Cities. BioScience, 66(3), 198–212. https://doi.org/10.1093/biosci/biw002
12. Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ, 339:b2535. https://doi.org/10.1136/bmj.b2535
13. Nijhuis, S., & Jauslin, D. (2015). Urban landscape infrastructures: Designing operative landscape structures for the built environment. Research in Urbanism Series, 3, 13–34. https://doi.org/10.7480/rius.3.874
14. O'Brien, A. M., & Guckin, C. M. (2016). The Systematic Literature Review Method: Trials and Tribulations of Electronic Database Searching at Doctoral Level. Sage Research Methods Cases. https://methods.sagepub.com/case/systematic-literature-review-electronic-database-searching-doctoral-level
15. O'Donnell, E. C., Netusil, N. R., Chan, F. K. S., Dolman, N. J., & Gosling, S. N. (2021). International perceptions of urban blue-green infrastructure: A comparison across four cities. Water (Switzerland), 13(4). https://doi.org/10.3390/w13040544
16. Pickett, S. T. A., McGrath, B., & Cadenasso, M. L. (2013). The Ecology of the Metacity: Shaping the Dynamic, Patchy, Networked, and Adaptive Cities of the Future. In S. T. A. Pickett, M. L. Cadenasso, & B. McGrath (Eds.), Resilience in Ecology and Urban Design. Linking Theory and Practice for Sustainable Cities (Vol 3). Springer. https://doi.org/https://doi.org/10.1007/978-94-007-5341-9_28
17. Pickett, S. T. A., & Zhou, W. (2015). Global urbanization as a shifting context for applying ecological science toward the sustainable city. Ecosystem Health and Sustainability, 1(1), 1–15. https://doi.org/10.1890/EHS14-0014.1
18. Russo, A., & Cirella, G. T. (2017). Biophilic Cities: Planning for Sustainable and Smart Urban Environments. In R. Aijaz (Ed.), Global Policy: Smart Cities Movement in BRICS (pp. 153–159). Observer Research Foundation and Global Policy Journal.
19. Steiner, F. (2014). Frontiers in urban ecological design and planning research. Landscape and Urban Planning, 125, 304–311. https://doi.org/10.1016/j.landurbplan.2014.01.023
20. Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. Climate and Development, 4(4), 311–326. https://doi.org/10.1080/17565529.2012.745389
21. Wu, J. (2014). Urban ecology and sustainability: The state-of-the-science and future directions. Landscape and Urban Planning, 125, 209–221. https://doi.org/10.1016/j.landurbplan.2014.01.018
22. Xavier, A. F., Naveiro, R. M., Aoussat, A., & Reyes, T. (2017). Systematic literature review of eco-innovation models: Opportunities and recommendations for future

research. Journal of Cleaner Production, 149, 1278–1302. https://doi.org/10.1016/j.jclepro.2017.02.145

23. Xu, J., & Cornelissen, J. (2023). Disequilibrium and complexity across scales: a patch-dynamics framework for organizational ecology. Humanities and Social Sciences Communications, 10(1), 1–13. https://doi.org/10.1057/s41599-023-01730-x

24. Zhaxi, D., Zhou, W., Pickett, S. T. A., Guo, C., & Yao, Y. (2024). Urbanity mapping reveals the complexity, diffuseness, diversity, and connectivity of urbanized areas. Geography and Sustainability, 5(3), 357–369. https://doi.org/10.1016/j.geosus.2024.03.004

Anshrah Kidwai is an architect who earned her Bachelor's degree in Architecture with honour from Integral University, Lucknow. She is currently pursuing a postgraduate degree in Urban Regeneration at Jamia Millia Islamia. Her interests are deeply rooted in the integration of ecological principles within urban environments, emphasising sustainable, resilient and regenerative design. Her research focuses on urban ecology frameworks and strategies for integrating ecological principles into urban planning.
Email: kidwai23anshra@gmail.com

Dr Zeeshan Ibrar, is an architect and has a doctorate in Regional Planning and Disaster Management. Dr Ibrar is engaged as an Assistant Professor (Guest) at the Department of Architecture, Jamia Millia Islamia, New Delhi. He has a robust background in academia, with expertise in urban regeneration, disaster management, regional planning, Water Sensitive Urban Planning and Flood Resilience Framework. His publications reflect a keen interest in the Adaptive Capacity of Flood Affected Regions.
Email: gf.zibrar@jmi.ac.in

Dr. Nisar Khan (25047) is Professor at the Faculty of Architecture and Ekistics, Jamia Millia Islamia, New Delhi. He completed his graduation and postgraduation at AMU, SPA Delhi and IHS Netherlands respectively. His doctoral thesis on the architecture of unauthorised colonies of Delhi was awarded from JMI. In his 18 years of experience in teaching he has initiated the M. Arch. Urban Regeneration Program at JMI. His research work is published as well as presented in various journals and national and international conferences respectively and he has also delivered invited lectures at several reputed institutes. Dr. Khan is a recipient of Dutch Orange Knowledge Program fellowship twice in 2019 and 2022.
Email: nkhan2@jmi.ac.in

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala during 29-31 August 2024, under Stream II -The Significant Present

CLAY-STRAW BLOCK (CSB)

As Sustainable Building Material to Reduce Carbon Emission in Building Construction Sector

By Sharif Tanjir Ahmed

Abstract

Clay-straw block (CSB) is a concept that comes from the old mud house in the Indian subcontinent. It's a sustainable step for the future that reduces carbon emissions in our environment. Clay-straw block (CSB) is low-cost, eco-friendly, and sustainable option for construction. The aim of this research paper is to identify options that help to reduce carbon emissions in the building construction sector. The components for making this block are locally available. The methodology includes preparation of blocks with a mixture of clay soil, straw dust, gravel, sand, cement, lime, and water. Clay soil is a material that has enough plasticity and compressive strength for load bearing. Cement and sand act as stabilisers. The lime prevents shrinkage of the block. Gravel makes the block strong. And straw is the binding agent of the mixture, which reduces the weight and cracking of the block. Experimental test findings determined the mix proportion of CSB as 2% lime, 3% cement, 3% straw, 10% gravel (sieve size 4.75mm–15mm), 22-25% sand, 57-60% clay soil, and water (18–20%) from the dry mix. It is usable after drying in sunlight for 7–10 days. The durability and sustainability of the clay-straw block satisfied the required standard. In the frame structure and also in the load-bearing structure, it can replace the fire-burned brick and cement blocks, whose manufacturing process is harmful for our environment. After the experimental test, it was confirmed that CSB has lesser carbon emissions as compared with fire-burnt bricks by 85%–90%. CSB are also preferred in high-rise buildings because of its lower weight with respect to mud blocks and cement blocks. The findings indicate that this block is more sustainable and ecofriendly than any other block.

1. Introduction

Climate change is a key global issue. The continuous increase in greenhouse gas emissions, such as carbon dioxide (CO2), from non-renewable energy sources, is the primary driver of climate change. Construction industry accounts for a large percentage of carbon emission. A house or shelter is one of the most basic human needs. Currently in developing countries, building construction is increasing on a daily basis. For sustainable development, we should focus on construction materials. In Indian subcontinent, bricks and cement blocks are usual materials for construction. Because of compressive strength and availability of suitable soil, fire burnt bricks are the most popular material in this region. But fire burnt bricks and cement blocks are harmful to our environment. A large volume of carbon is emitted in our environment for producing bricks and cement blocks. For minimising the use of fire burnt bricks and cement blocks, a sustainable material is needed which can replace these materials with the similar features. On the other hands, in this area a huge amount of paddy straw is burnt in winter season for clearing agricultural fields leading to air pollution and producing carbon. Use of locally available materials for making construction is economically sustainable. The idea of clay-straw block comes from the concept of old rural mud house in Indian subcontinent. The mixture making process for mud wall was old and sustainable. The ingredients of the mixtures are locally available such as mud, sand, straw etc. The straw fibres provide good cohesion between the mud layers. Clay-straw block has several advantages over conventional fired brick or concrete masonry. This block performs considerably better in environmental terms than fired bricks as they have significantly less

embodied energy, contribute fewer CO2 emission and help to promote the local economy and local labour.

1.1 Aim and Objectives

The aim of this research is to identify options that help to reduce carbon emission in building construction sector, to make eco- friendly building material with low carbon emissions having required strength.

To reduce carbon emission from agricultural waste and provide block stability.

To meet the economic requirements of the local regions by reducing dependence on outside sources and ensuring low-cost alternative.

2. Literature Review

For manufacture of concrete blocks, the recommended ratio of coarse to fine aggregates with cement is 1:9 with 10% of all mix of cement.

For making stabilised mud blocks, blocks produced from10% cement (C10), 10% cement with 3% coir fibre (C10C), 10% cement with 3% plastic fibre (C10P) have compressive strength and total water absorption values above the recommended minimum values for structural work. (Vinu Prakash, 2016).

Mud-Concrete Block mix proportions were minimum of 4% Cement, Fine ≤ 10% (≤ sieve size 0.425 mm), Sand 55–60% (sieve size 0.425 mm ≤ sand ≤4.75 mm), Gravel 30–35% (sieve size 4.75 mm ≤ gravel≤ 20 mm) with a water content of 18% to 20% from the dry mix. (F.R. Arooz, 2018).

3. Methodology

3.1. Components Collection:

The components of this block are clay, sand, straw, gravel, cement and lime.

Clay: Clay is a strong stabiliser. The dry clay is very hard, and it can withstand a high load. The clay soil offers good compressive strength.

Sand: Sand plays a crucial role in reducing water absorption in the block.

Straw: Straw will act as a binding agent. Also, it will reduce the block weight.

Gravel: Gravel will enhance the compressive strength of the block. When mixed with clay, cement, and sand, it increases the block's strength. The size of the gravel will be 4.75mm to 15mm.

Cement: Portland cement is a stabiliser, and also it acts as a binding agent after mixing with water. It helps to coagulate the mixture.

3.2. Mould: Moulds were prepared with the dimensions of 254 mm x 127 mm x 76 mm. The mould was prepared using a wooden frame.

3.3. Mix proportion: The mixture has been prepared with 2% lime, 3% straw, 3% cement, 10% gravel, 22-25% sand and 57-60 % clay soil. After this mixture 18-20% water will be mixed with the dry mix.

3.4. Preparation of block: The ingredients are thoroughly mixed in a mixing machine. Then, the mixture is placed in a wooden frame mould to create a perfectly shaped block. After this, it is dried in sunlight for a minimum of 7-10 days to make it usable.

4. Data Analysis and Findings

4.1. Compressive strength

Table 1: compressive strength analysis
Source: Author

Items	Weight(kg)	compressive strength (N/mm2)
Only soil	3.6	1.06
5% cement with soil	3.63	1.33
5% cement, 2% straw	3.86	2.38
Burnt brick	3.5	3.5
Clay-straw block	**3.57**	**2.52**

4.2. Water absorption

After 24 hours of water absorption, the specimen is taken out. The weight of the block before water absorption is W1 and after absorption is W2. The calculation of water absorption percentage is as follows:

Water absorbed = (W2-W1) / W1 × 100%

Table 2: Water absorption
Source: Author

Items	Water absorption percentage (%)
Only soil	23.61
5% cement with soil	19.83
5% cement, 2% straw	19.56
Burnt brick (A-grade)	15
Clay-straw block	18.92

4.3. Carbon emission

In cement industries, 0.9 kg of carbon is emitted for 1kg of cement production. And 785g of carbon is emitted for every 1 kg of lime produced, of which 76.21% is absorbed by itself, and 23.79% is released into the environment. In brick manufacturing, 244g of carbon is emitted per kilogram of burnt brick produced. The information is tabulated below.

Table 3: Carbon emission analysis
Source: Author

Items	Carbon emission(gm) per block
5% cement mud block	163.35
10% cement concrete block	324
Fire burnt brick	854
Clay-straw block	109.39

5. Results and Discussion

In Table 1, compressive strength data is listed. Here, the compressive strength of the soil block is 1.06 N/mm2, the soil block with 5% cement is 1.33 N/mm2, soil with 5% cement and 2% straw is 2.38N/mm2, burnt brick is 3.5N/mm2, and the clay-straw block is 2.52N/mm2 by machine testing.

In Table 2, the water absorption percentage is listed. The water absorption of the soil block is 23.61%, the soil block with 5% cement is 19.83%, the soil block with 5% cement and 2% straw is 19.56%, fire burnt brick is 15%, and the clay-straw block is 18.92%.

The main focus of the study was to identify methods to reduce carbon emissions in construction processes. In the data analysis part, various kinds of blocks and bricks are analysed for comparison with clay-straw blocks. After calculating these results are found that:

1. Carbon emission of CSB (clay-straw block) is 33.04% less than 5% cement mud block.
2. Carbon emission of CSB is 66.24% less than 10% cement concrete block.
3. Carbon emission of CSB is 87.2% less than fire burnt brick.

On the other hand, 25 Tg (1Tg = 1000000 tones) carbon and 0.02Tg sulphur are emitted annually for burning rice straw in southeast Asia. Sulphur and carbon are very harmful to our environment. This can be reduced by using CSB.

6. Conclusions and Recommendations

Building with earth and straw is appropriate and cost and energy-efficient technology that has a great future. By using appropriate structural techniques and stabilisation methods, CSB can be used in any building and, nearly every climate. By incorporating components such as rice straw, the strength of the block is increased. Air pollution due to burning straw will be reduced. After all analysis, it is proved that the clay-straw block is a more sustainable and more eco-friendly construction material than all others and reduces more percentage of carbon emission. It reduces carbon emissions in comparison with fire-burnt bricks by 87.2%, hence the usage of CSB is recommended.

Cited References

i. Journal Article

1. Vinu Prakash., Amal Raj., Aravind S., Basil Mathew., Sumith, V. R. (2016). Studies on stabiliser mud block as a construction material: Authority, International Journal of Innovative Research in Advanced Engineering (IJIRAE).
2. Kamalakannan, Dr. S., Ranganathan, Dr. A., Vijay Kumar, Dr. M.H., Mr. Sreekumar, N.R., Anjali Baby, Ms. (2019). Stabilised mud block: Authority, Journal for innovative development in pharmaceutical and technical science.
3. Somarathan, H.M.C.C., Sampath, K.A.C., Jayathilaka, K.G., Ranasinghe, A.W.L.H., Halwatura, R.U., Perera, A.A.D.A.J. ('n.d.'). Feasibility study on a mud block with straw: Authority, 'n.d.'
4. Frasson, Jr., Artêmio., Casali, Juliana Machado., Oliveira, Alexandre Lima., Prudêncio, Jr., Luiz Roberto. (2012). A mix design methodology for concrete block unit: Authority, 15th international brick and block masonry conference.
5. Aroz, F.R., Halwatura, R.U. (2018). Mud-concrete block (MCB): mix design & durability characteristics: Authority, www.elsevier.com/locate/cscm
6. Fayomi, G.U., Mini, S.E., Fayomi, O.S.I., Ayoola, A.A. (2019). Perspectives on environmental CO2 emission and energy factor in Cement Industry: Authority, International Conference on Energy and Sustainable Environment.
7. Lekshmi, Sathyababu., Kathu, S., Ampady, Aromal., Jebin, Muhammed., Vineeth, V., Duithy, George. (2016). Studies on stabilised mud block as a construction mud block: Authority, International Journal of Scientific & Engineering Research.
8. Owoeye, Femi Timothy., Adinife, Patrick Azodo., Williams, Kwari Joshua. (2021). The Effect of Burnt Clay Brick Production Process on the Compressive Strength and Water Absorption Properties: Authority, SNRU Journal of Science and Technology.
9. Vignesh, N. P., Mahendran, k., Arunachelam, N. (2020). Effects of Industrial and Agricultural Wastes on Mud Blocks Using Geopolymer: Authority, https://doi.org/10.1155/2020/1054176
10. Ba Cuong Nguyen., Nikolaos Mihalopoulos., Jean-Philippe Putaud., Ba Nguyen. (1994). Rice straw burning in Southeast Asia as a source of CO and COS to the atmosphere: Authority, JOURNAL OF GEOPHYSICAL RESEARCH.
11. Nitin, G. Kulkarini., Anand, B. Rao. (2016). Carbon footprint of solid clay bricks fired in clamps of India: Authority, Journal of Cleaner Production.

ii. Book

Rangarajan, Er.T., B.E,M.Sc (Stuct.Engg),F.I.E,C.E,P.E. (n.d.). Importance of lime in building construction.

Sharif Tanjir Ahmed is a student at the Department of Architecture at Pabna University of Science and Technology in Bangladesh. He is currently based in Narail, Dhaka, Bangladesh.
Email: tanjirhossen412@gmail.com

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala during 29-31 August 2024, under Stream III: The Projected Future

Retrofitting and Adaptive Reuse

The New Face of Urban Architecture in India

(Case Study: The Extension of Father Agnel School, Greater Noida, UP)

By Ar. Christopher Paul

1. Introduction

India is experiencing rapid urbanisation, with its cities growing at an unprecedented rate. This urban expansion presents a significant challenge: balancing modernisation with ecological considerations. The traditional approach of demolishing old structures to build new ones is increasingly seen as unsustainable, both economically and environmentally. As a result, retrofitting and adaptive reuse have emerged as viable solutions, offering a way to modernise urban infrastructure while preserving cultural heritage and minimising environmental impact. This paper explores the role of architects in this transformative process, highlighting the technical, economic, and cultural benefits of retrofitting and adaptive reuse in urban India, with a case study of Fr. Agnel School, Greater Noida.

2. The Need for Retrofitting and Adaptive Reuse

India's urban population is projected to reach 600 million by 2031, necessitating significant infrastructure development. Many buildings in urban areas have reached or surpassed their maturity, with some structures showing signs of structural weakness. These buildings, often constructed during the mid-20th century, are integral to the urban fabric but require updates to meet contemporary standards and demands.

3. Economic and Environmental Considerations

Demolishing and reconstructing buildings is not only expensive but also environmentally detrimental. The construction industry is a major contributor to carbon emissions, resource depletion and waste generation. By contrast, retrofitting and adaptive reuse offer more sustainable alternatives. These processes involve refurbishing existing buildings to improve their functionality and efficiency, thereby extending their lifespan and reducing the need for new construction materials.

4. The Role of Architects in Retrofitting and Adaptive Reuse

- **Assessing Structural Integrity:** Architects play a crucial role in the retrofitting and adaptive reuse of buildings. The first step in this process is assessing the structural integrity of the existing building. This involves detailed inspections and analysis to determine the building's current condition and identify areas that require reinforcement or modification. Advanced technologies, such as 3D scanning and structural health monitoring systems, are often used to facilitate this assessment.
- **Understanding Infrastructure and Functional Requirements: E**valuation of services like electrical, plumbing, and HVAC systems, as well as considering the building's overall layout and spatial organisation is important. The goal is to ensure that the retrofitted building can meet contemporary standards for safety, comfort and efficiency while maintaining its historical and cultural significance.
- **Preserving Architectural Vocabulary:** One of the most challenging aspects of retrofitting and adaptive reuse is preserving the architectural vocabulary of the existing building. This means

retaining the distinctive architectural features and aesthetic elements that define the building's character. Architects must strike a delicate balance between modernising the building and preserving its historical integrity. This often involves creative solutions, such as integrating modern materials and technologies in a way that complements the original design.

5. Case Study: Fr. Agnel School

Background

Fr. Agnel Schools, and Agnel Charities Society established in 1965, have been a cornerstone of the community, providing quality education for decades. However, this particular building block was only 12 years old, and hasn't shown any signs of aging, but it no longer meets current educational and safety standards. The decision to retrofit and adaptively reuse the school was driven by the need to augment and modernise the facilities while preserving the school's historical significance and minimising environmental impact. In addition, the fact that the school campus had exhausted its permissible ground coverage, but much FAR area balance, required for the extension was significant. The front block was thus selected, due to its structural capacity and, logistically it was convenient, as it had minimal classes and mostly administration of the school. The administration was shifted to another block, during the course of the construction.

Fig. 1: Showing the existing Building of Fr. Agnel School, Greater Noida

6. Retrofitting Process

- Structural Assessment

The first step in the retrofitting process was a comprehensive structural assessment. Using advanced technologies such as NDT and structural health monitoring, the Architect and Structural Engineers evaluated the building's integrity, identifying areas needing reinforcement. The assessment revealed that while the core structure was sound, several areas required significant updates to meet contemporary safety standards.

The Column sizes were 230mm standard on one face, while the other side varied from 300mm to 600 mm. The building was designed as an RCC and Load-Bearing hybrid structure. Though the strength of concrete and health of steel was fairly good, the size of columns did not allow for further expansion. There was a need for larger sized columns to attain 4 new floors. An exo-skeletal structure system was devised to take up the additional new floors without them impacting much load on the existing structure.

- Infrastructure Upgrades

The next phase involved upgrading the school's infrastructure. This included modernising the electrical and plumbing systems, drainage and Rain water harvesting, and installing energy- efficient systems of CCTV, Fire Alarm, Data and telephone etc. and ensuring compliance with current accessibility standards. Also, Solar panels are proposed to be installed on the roof to reduce the building's carbon footprint and provide a sustainable energy source.

- Architectural Preservation

Preserving the school's architectural vocabulary was a priority. The distinctive façade and original design elements were meticulously restored and incorporated in the design, while the interior spaces were reconfigured to enhance functionality and comfort. Modern materials and technologies were integrated subtly to maintain the building's institutional character.

Elements such as the box windows, RCC Jaali work, grit finish exterior have been taken up from the existing building design and incorporated further in the extension. The crown and shoulder design of the top of the front elevation seems to be part of the original building and compliments the existing structure.

- Outcomes and Benefits

The retrofitting of Fr. Agnel School, Greater Noida resulted in a modern, energy-efficient building that meets contemporary educational standards while preserving its historical significance. The project demonstrated that extensions through retrofitting and adaptive reuse are viable solutions for augmentation of aging infrastructure, providing economic, environmental, and cultural benefits. The school's revitalisation is strengthening the community and setting a precedent for future projects of similar nature in the region.

7. Technical Aspects of Retrofitting and Adaptive Reuse

- Structural Reinforcement

One of the primary technical challenges in retrofitting is reinforcing the existing structure to meet contemporary standards. This often involves adding new support elements, such as steel braces or reinforced concrete, to improve the building's stability and load-bearing capacity.

The materials used enhance structural performance without adding significant weight. In this building, an exo-skeletal system was adopted. Wherein new combined footings were designed to overlap and encapsulate the existing isolated footings. Thus, creating a larger foot print of the foundation, for increased height of the building. A set of new columns rose all around the building, which wrapped around the existing 2 storeys, and then went up to take up 4 new floors.

Showing Re-strengthened foundations and Exoskeletal structure

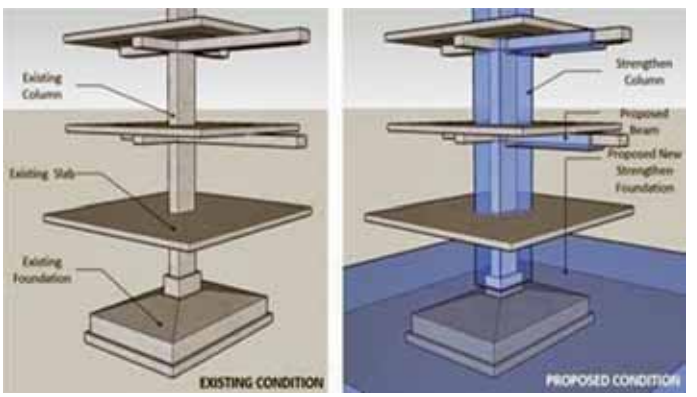


Fig. 2: Showing re-strengthening of columns

- Energy Efficiency Improvements

Improving energy efficiency is a key goal of many retrofitting projects. This can involve upgrading insulation, installing energy-efficient windows and lighting and incorporating renewable energy sources, such as solar panels. These improvements not only reduce the building's environmental impact but also lower operating costs and enhance occupant comfort

- Modernising Building Systems

Modernising the building's electrical, plumbing, and HVAC systems is another critical aspect of retrofitting. This often involves replacing outdated equipment with modern, energy- efficient alternatives. In some cases, new systems are integrated with smart building technologies, allowing for greater control and optimisation of energy use.

8. Economic Benefits of Retrofitting and Adaptive Reuse

- Cost Savings

Retrofitting and adaptive reuse can offer significant cost savings compared to new construction. By preserving and upgrading existing structures, developers can avoid the high costs associated with demolition and site preparation. Additionally, many retrofitting projects qualify for government incentives and grants aimed at promoting sustainable development.

In this example of Fr. Agnel School, Greater Noida, we saved about ₹ 2 Cr by saving the existing building. Not only that, about 6-9 months of time was also saved by not indulging in its demolition. Also, we saved the building along with its architectural character, which is the face of the school.

Fig. 3: Showing Retrofitting of foundation and re-strengthening of column

- Increased Property Value

Retrofitting and adaptive reuse can also increase the value of a property. Modernised buildings with improved energy efficiency and updated infrastructure are often more attractive to tenants and buyers. This can lead to higher rental rates and property values, providing a strong financial return on investment.

Since this is a school, we achieved more built-up area in almost the same amount of ground coverage. Thus, increasing the overall value of the whole development.

Fig. 4: Showing Exoskeletal structure growing around the existing building

Fig. 5: Showing The exoskeletal grown up to 5th floor level

9. Cultural and Social Benefits

- Preserving Cultural Heritage

One of the most important benefits of retrofitting and adaptive reuse is the preservation of cultural heritage. Many of India's urban buildings have significant historical and architectural value. By preserving these structures, cities can maintain their unique character and sense of identity. This not only enriches the urban environment but also promotes cultural tourism and economic development.

In this school building, our focus block was the front block, which bears the school emblem and name. And, it has been the face of the school for the last 10 years. To maintain the institutional look and character of the institution, this exercise was pivotal.

- Community Engagement and Revitalisation

Retrofitting and adaptive reuse can also play a key role in community engagement and revitalisation. By repurposing old buildings for new uses, such as community centres, cultural venues, or affordable housing, architects can help to revitalise urban areas

Fig. 6: Showing Artistic impression of the proposed building

and create vibrant, inclusive communities. This can lead to increased social cohesion and improved quality of life for residents.

10. Challenges and Solutions

- Technical Challenges

Retrofitting and adaptive reuse projects often face significant technical challenges. These can include structural issues, such as inadequate foundations or deteriorated materials, as well as logistical challenges, such as working within the constraints of an existing building. To address these challenges, architects must employ innovative design solutions and collaborate closely with engineers and contractors.

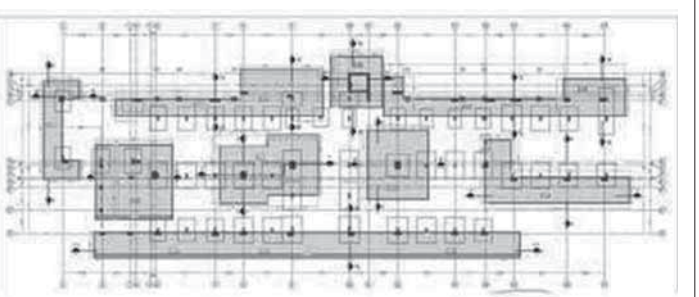


Fig. 7: Showing Foundation Plan, old and proposed footings

- Regulatory Hurdles

Navigating regulatory requirements can also be a challenge. Many retrofitting projects must comply with strict building codes and preservation regulations, which can be time-consuming and costly. To overcome these hurdles, architects must work closely with regulatory agencies and leverage their expertise in building codes and standards.

- Balancing Modernisation with Preservation

One of the most significant challenges in retrofitting and adaptive reuse is balancing modernisation with

preservation. This requires a careful and nuanced approach, where architects must find ways to integrate modern amenities and technologies without compromising the building's historical and architectural integrity. Creative design solutions, such as concealed modern elements and the use of complementary materials, are often key to achieving this balance.

11. Conclusion

Retrofitting and adaptive reuse represent the new face of urban architecture in India, offering a sustainable and economically viable solution to the challenges of modernisation. Architects play a crucial role in this process, from assessing structural integrity and understanding infrastructure needs to preserving architectural vocabulary and integrating modern technologies. Through successful examples like Fr. Agnel School - Greater Noida, it is clear that retrofitting and adaptive reuse can enhance urban environments while preserving cultural heritage and minimising environmental impact. As India continues to urbanise, embracing these strategies will be essential for creating resilient, vibrant, and sustainable cities.

References

1. Bhattacharya, P. (2021). Urbanisation in India: Population growth and infrastructural challenges. Journal of Urban Development, 34(2), 45-58.
2. Mehta, S. (2020). The aging infrastructure of Indian cities. Urban Renewal Journal, 28(3), 10-23.
3. Singh, R., and Kaur, P. (2019). Environmental impacts of the construction industry in India. Environmental Management Review, 22(1), 67-81.
4. Sharma, A. (2018). Sustainable architecture: Retrofitting and adaptive reuse in India. Green Building News, 12(4), 50-59.
5. Gupta, M., and Sharma, D. (2017). Technological advancements in structural health monitoring. Construction Technology Today, 15(1), 35-42

All images courtesy the Author

Ar Christopher Paul (A21289) has completed his B. Arch from BIT Mesra (2010) and M. Plan (Housing) from SPA Delhi (2015). He has been active in Practice, Research and Academics for about 15 years. He is the Founder and Principal Architect of Chistopher Paul Architects and he is Consulting Architect to District Panchayti Raj Office, GB Nagar. He has also published a book on the Real Estate of Unauthorised Colonies of Delhi. His area of interest has been retrofitting and real estate.
Email: ar.cp.conage@gmail.com

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, during 29-31 August 2024, under Stream 3: The Projected Future.

Sustainability of Beaches in an Urban Context

by Ms. Aiswarya A. and Ar. Ganga Krishnan

The article explores the critical importance of sustainable development for beaches, focusing on Kovalam beach in Thiruvananthapuram, Kerala, India. It examines how urban beaches can serve as significant recreational landscapes within an urban context, evaluating their social utility, geological composition and lithological characteristics as essential factors for sustainable beach planning and management.

The increasing urbanisation of coastal areas intensifies pressure on ecosystems due to issues such as overcrowding, degradation of the ecosystem, artificialisation etc. This results in resource overexploitation, fragmentation of vegetation, clearing, littering, collectively diminishing the aesthetic appeal of beaches and reducing their effectiveness as open urban spaces.

The study adopted a methodological approach tailored to its research objectives, incorporating variables such as social utility, accessibility, safety and security, seating spaces, lighting, etc. It also analysed the lithological aspects including soil type, soil colour and the geomorphological features specific to Kovalam beach. Through surveys capturing beach users' perceptions and satisfaction regarding these factors, the research aimed to inform sustainable beach management practices. The findings from this study provide valuable insights into indicators for future sustainable development along beachfronts, advocating for integrated management approaches. Recommendations include infrastructure enhancement such as community toilets, well-planned roads, sustainable seating arrangements and pedestrian pathways without hindering the local community activities. Furthermore, a waste management strategy aligned with sustainable Development Goals 14 is crucial for ensuring environmental sustainability.

1. Introduction

Urbanisation is putting pressure on coastal ecosystems, particularly in exclusive economic zones (EEZs) like the Indian Coastline. These zones are crucial for commercial, residential, transport and national defense infrastructure. Human activities, such as clearing, fragmentation of vegetation, overexploitation, and pollution, are causing environmental, social and cultural degradation. Coastal tourism also contributes to overcrowding, artificialisation and ecosystem degradation. Additionally, human activities and waste production contribute to degraded soil, water and air quality in coastal cities. Beaches are crucial for tourism as they attract tourists, contribute to local, national and international revenue and offer employment opportunities for local populations. They are ecologically fragile areas, providing habitats for a variety of flora and fauna, and influencing climatic fluctuations. These changes can lead to habitat destruction, beach degradation and spread of disease s. The potential of beaches in tourism is significant, as they help conserve coastal habitats and landscapes, promote sustainable urban growth and maximise local revenue. Developing region-specific economic sectors and promoting cultural initiatives can attract more visitors, promoting sustainable urban growth and local revenue. User perception and satisfaction are essential in coastal tourism, as they influence the choice of tourist destinations and consumption of products and services. Monitoring tourist satisfaction helps plan infrastructure and designs accordingly. The paper aims to study the significance of sustainable development of beaches,

taking the case of Kovalam, Thiruvananthapuram in Kerala, India. This will ensure that the authorities bring more facilities and services through new plans and strategies there by attracting more tourists, bring benefits to the industries and also ensures the sustainable development of the beach precincts.

2. Need of the Study

Beaches are significant due to their potential in attracting tourists. Tourism is the largest economic activity that promotes the revenue of the country at local, national, international level. It provides larger employment opportunities for the local population and recreation avenues for the people who live in urban areas, mainly for the people who are living in an extent of 50 km. Beaches are ecologically- fragile areas and it is the habitat for a wide variety of flora and fauna, a space for various living organisms like sea turtles, birds to lay eggs and hatch and a variety of crabs. This makes the beaches relevant for the balance of the ecosystem which in turn has significant influence on the climatic fluctuations. These climatic variations cause the changes in wave movement and that results in serious threat to coastal communities, due to habitat destruction, beach degradation and disease spread.

The potential of beaches in tourism is important, as the conservation of coastal habitats and landscapes is crucial for ecological balance. Developing region-specific economic sectors linked with tourism and promoting cultural initiatives can attract more visitors. These efforts, in turn, promote sustainable urban growth and maximise local revenue. User perception and satisfaction are considered an important aspect of coastal tourism, as they are very crucial in the choice of tourist destination and the consumption of the products and services in the destination. Proper monitoring of the tourist satisfaction acts as a tool for planning the infrastructure and designs according to the needs of the domestic and international tourists (Brščić & Šugar, 2020).

3. Aim and Objectives

The paper aims at understanding the significance of sustainable development of beaches, taking the case of Kovalam, Thiruvananthapuram, Kerala, India. Kovalam is a pristine beach and is a famous attraction amongst domestic and international tourists. It has a massive coastline stretching over an area of 15 km.

The major objectives of the study are:

a. To assess the significance of beaches as a public space in an urban context.
b. To investigate the ecological aspects of the crescent beaches, mainly emphasising the assessment of their carrying capacity and coastal management strategies for ensuring sustainability of beaches.
c. To explore parameters of public space dynamics at beaches.
d. To examine the current scenario of Kovalam beach and management strategies.

The Kerala tourism department is planning to implement a development project worth 93 crores in Kovalam Beach, mainly focusing on the development of the lighthouse (figure 1) and Hawa beach, renovation of existing walkways, construction of diaphragm wall, a toilet block and the development of Adimalathura beach. Kovalam Beach attracts many tourists due to its natural beauty and ecological value. Authorities are introducing new infrastructure projects, but sustainability is often neglected. This study addresses the sustainability of development at Kovalam Beach.

Figure 1: Lighthouse Beach
Source: https://www.newindianexpress.com/cities/thiruvananthapuram/2023/Apr/27/tourism- department-plans

4. Limitations of the Study

a. The study is limited by the availability of data and duration of the research period.
b. The primary study is limited to Kovalam beach.
c. The findings and inference may face challenges as the perspective of the local community regarding the potential of beach may vary.

5. Literature Review

a. Sustainability of Beaches

Coastal environments are formed where the land and the ocean meet. Urbanised societies are highly dependent on resources for food, pharmaceuticals, energy and minerals. The coastal urbanisation results in changes to environment and ecosystems due to human activities such as clearing, fragmentation of vegetation, over exploitation, pollution etc. (Steven et al., 2023). The increase in coastal tourism has negatively affected environmental, social and

cultural sustainability. Overcrowding, artificialisation and ecosystem degradation are caused by coastal tourism and the relationship with service demand, public use and environmental sustainability. (Dadon, 2018; Lukoseviciute & Panagopoulos, 2021). The human activities and the production of waste from the growing population will result in degraded soil, water and air quality in and around coastal cities (Burt et al., 2019). Marine litter is a growing environmental problem worldwide and is responsible for reducing the aesthetic quality of the beaches. Marine litter could be defined as 'solid material of human origin' that are discarded in the sea or reach the sea through waterways or domestic and industrial outfalls. They can be of two sources of marine litter by humans i.e. sea-borne and land-based.

b. Ecological Aspects of a Crescent Beach

i. Carbon input metrics: Biological inputs are the primary driving force of sandy beach ecosystems. The amount of biological input is determined by wrack deposition and potential detrital input from nearby Kelp beds (Patsch et al., 2021).

ii. Landscape integrity metrics: Human barriers do not extensively occupy integration regions, low relief barriers occupy intermediate integration, and strong integration occurs near dune, wetland, riparian, grassland, and shrub land (Patsch et al., 2021).

iii. Carrying capacity: Physical carrying capacity refers to the number of individuals a beach can accommodate, while social carrying capacity refers to the discomfort caused by overcrowded individuals (Da Silva, 2002).

6. Current Scenario of Kovalam Beach

The current scenario of Kovalam is that the recent pandemic Covid 19 had both positive and negative impacts the beach. The positive impact was that as the influx of the population had reduced, a few marine species returned and the water pollution also reduced. Recent problems were waste disposal, Beach erosion, biodiversity reduction.

7. Case Studies

Beach User Satisfaction and Concerns

a. Cenang Beach

The beach's white sand and fine texture make it comfortable for visitors. The average temperature is 28 degrees celsius, with high sunny days and absence of intense waves and winds. The presence of vegetation plays a crucial role in nature conservation despite urbanisation.

i. Accessibility, Facility and Safety
The beach's parking areas are controversial due to urbanisation and overcrowding. Facilities like toilet spaces, trash bins, showers and foot wash spaces are lacking due to increasing beach accommodations and restaurants/bars. The absence of a security kiosk and inappropriate position of the lifeguard tower are safety issues.

ii. Landscape Details and Accessibility
The beach is mainly accessed due to its pleasant scenery and proximity to the most active part of the island. The beach infrastructure is inadequate and signage is not present.

iii. User's Perception of Beach Crowding
Overcrowding is due to uneven distribution of services and facilities. The enjoyment of visiting the beach is not affected or increased by the presence of other users.

iv. User's Future Trip
Majority of users agree to visit the beach precinct except during peak season. Few respondents are willing to experience spatial displacement due to crowding. Beach users are most satisfied with the natural and physical characteristics of the beach and most dissatisfied with environmental issues. It was recommended to remove abrasive material, litter, installing new toilets, showers and foot wash, and adding security kiosks.

v. Inference
The above study helped to analyse the parameters for determining the beach quality of the lighthouse and Hawa beach extent and for conducting live case study of Veli and Varkkala beaches.

8. Methodology

a. Secondary study

- Understanding the beach sustainability and beach assessment tools.
- Understanding the ecological aspects of the beaches.
- Background study of Kovalam beach, Lighthouse beach and Hawa beach.

b. Primary study

- Understanding the parameters for beach user perception and satisfaction through the case study of Cenang beach, Malaysia.
- Live case study of Veli beach and Varkkala beach.
- Site study at Hawa Beach and Lighthouse Beach.
- Conducting questionnaires/ surveys among the people in Thiruvananthapuram city
- Observational and user perception analysis of the extent of the study area.

c. Conclusion

- Analysing the parameters to the data obtained from survey s and case study

9. Data Analysis and Findings

The study of the beach quality was conducted by the analysis of beach amenities first, then assessment of geomorphological profile of the beaches and lithological aspects of Lighthouse and Hawa beach, live case study at Veli and Varkkala. This was evaluated by conducting a primary field observation, through questionnaire survey, among the people living in the Thiruvananthapuram city area and by collecting data on recent infrastructure at the beach precinct from Directorate of Tourism. This was designed to comprehend the need of sustainability of beaches in an urban context.

The survey data revealed that beach visitation habits, preferences and perceptions are influenced by various factors. The majority of respondents fall within the 20-40 age group (83.5%), with young to middle-aged adults being the primary beachgoers. The primary reason for visiting the beach is its proximity, followed by playing sports (27.2%) and relaxing (1.1%). Varkkala Beach is the most frequently visited beach (22%), followed by Veli and Kovalam Beach at 15.4%.

Varkkala Beach is perceived as the most beautiful beach, with 52.7% of respondents favouring it. Cleanliness of beaches is also a factor, with 43.3% of respondents considering it the cleanest and only 18.9% considering Kovalam beach to be clean. Varkkala Beach has the most adequate parking space (37.1%), followed by Veli Beach(16.9%) and Kovalam beach(9.4%).

More than half of respondents (55.3%) feel that none of the beaches have adequate toilet spaces and changing rooms. Kovalam beach at 9.4% was ranked the lowest because of the poor maintenance. All beaches (14.6%) and Veli Beach (12.4%) are seen as less adequate, suggesting a need for improvement in seating and lighting across several beaches. The seating spaces, lighting and pedestrian paths are similarly present in the beach precincts, but they are either poorly maintained or less in number, which causes discomfort to the beach users and causes people to less frequently visit the beach as a leisure space for family and groups. The inadequate light causes the visitors difficulty in understanding the spaces and hinders easy accessibility. The pedestrian paths are limited to the entrance space of the beaches and near park spaces, which makes it difficult for the elderly and children to walk along the beach, and the accessibility is limited.

Satisfactory safety and security standards are considered the best by 32.2% of respondents, followed closely by Varkkala Beach (26.8%). However, 21.8% of respondents feel that none of the beaches meet satisfactory safety standards. Accessibility of beaches is considered the most important factor with Veli Beach being the most accessible (30.3%). Safety and security were mainly under the lifeguard aid post, police aid post and DTPC. All the above services are limited to morning 6.00 am to 7.00 pm in the evening, which is unfavorable for the beach users' safety. The inappropriate position of the lifeguard aid post results in reduced visual and audio connectivity which may explain the fact that the respective authorities and beach managers did not or paid less attention to the aspect of security and safety of the beaches.

10. Results and Discussion

The study reveals that the beaches in Kovalam lack sufficient facilities and amenities to attract people as urban landscapes. Beach measurements and effective strategies are needed to revitalise the beaches, as recent beach projects have made significant positive and negative impact on the shores. Beach users' perceptions are crucial for the sustainable management of beaches. They are satisfied with the beach nature and accessibility, but the worst-rated aspects are lighting, toilet facilities, changing rooms and seating spaces.

Coastal management strategies, such as soft and hard techniques, can be employed to revitalise the beach shores. Ecological parameters and guidelines include dune stabilisation, gabions, cliff stabilisation, beach replenishment, sustainable use of coastal resources and maintaining ecological character. Infrastructure guidelines include enhancing the beach as an edge, improving accessibility and roadways, sustainable planning of more seating space, and prepare integrated management plans (IMPs) considering local community's needs. Sustainable development goals include reducing marine pollution by implementing SDG goal 14 and protecting the coastal ecosystem based on SDG goal 14.2 by implementing sustainable management approaches. The study also emphasises the importance of integrating management plans (IMPs) considering the needs of local communities, such as dispensaries, schools, public rain shelters, community toilets, roads, water supply, drainage and sewerage. Tackling the above issues with the above-mentioned strategies are a tedious task but can be initiated by proper long-term effort from public and private enterprises and from the users within the urban context of Thiruvananthapuram.

The immediate task, therefore, for the local authorities in particular and the state government in general, was to articulate an intervention to ensure the public facilities provided are satisfying the needs of the local, domestic and international tourists and in turn creating an ecologically sustainable and beneficial resources.

11. Conclusions and Recommendations

It can be seen that the beach users' perception is very important and is a useful tool in the planning of the sustainable management of beaches. Although the overall user satisfaction of the respondents living in the precincts of the Thiruvananthapuram city was moderate, beach users were not satisfied with all aspects of the beach.

Based on the data collected for Veli beach, Kovalam beach and Varkkala beach, users were found to be were very satisfied with the beach nature, accessibility and least satisfied with lighting, toilet rooms, changing rooms and seating spaces. These findings highlight the need for attention and consideration of authorities and local stakeholders to identify the issues and monitor the beach users' satisfaction as a valuable tool for sustainable beach management. This also ensures that the opinions of the residents was considered which will build their trust and loyalty. Ecological conservation is more important than other functions as it is the primary reason of the users' visit to the beach.

Local authorities should pay more attention to beach cleanliness issues and improve the facilities associated with toilet rooms, changing rooms, feeding rooms and their easy accessibility from the beach shore. In addition, more attention should be paid on the security system and safety in these areas. Also, comfort of the people is an important factor so recreational services and seating spaces should be provided in adequate quantity. Mainly in the urban context, local residents, domestic tourists and international tourist will be mostly coming in groups, so the users of the urban beaches may expect the heavy crowding and this should be managed with effective planning of the spatial facilities and services within the precincts of the beach. The data collected about the beaches in the Thiruvananthapuram city and Kovalam beach explains the ecological, geomorphological and lithological potential of the beaches which is existing in naturally and its sustainable management is important for the future generations. These finding will help the authorities bring more facilities and services through new plans and strategies, thereby attracting more tourists, bring benefits to the related industries and also ensure the sustainable development of the beach precinct.

References

Brščić, K., & Šugar, T. (2020). Users' perceptions and satisfaction as indicators for sustainable beach management. Tourism and hospitality management, 26(1), 33-48. Ronen Alkalay, G. P. (2006). Clean -Coast Index - A New approach for beach cleanliness assessment.

Burt, J. A., Killilea, M. E., & Ciprut, S. (2019). Coastal urbanisation and environmental change: Opportunities for collaborative education across a global network university. Regional Studies in Marine Science, 26, 100501.

Da Silva, C. P. (2002). Beach carrying capacity assessment: how important is it?. Journal of Coastal Research, (36), 190-197.

Dadon, J. R. (2018). Beach management, beyond the double standard for client demands and environmental sustainability. Beach Management Tools-Concepts, Methodologies and Case Studies, 619-634.

Goda Lukosevicuite, T. p. (2021). Management priorities from tourists perspectives and beach quality assessment as tools to support sustainable coastal tourism. 1-2.

Lukoseviciute, G., & Panagopoulos, T. (2021). Management priorities from tourists' perspectives and beach quality assessment as tools to support sustainable coastal tourism. Ocean & Coastal Management, 208, 105646.

Patsch, K., King, P., Reineman, D. R., Jenkins, S., Steele, C., Gaston, E., & Anderson, S. (2021). Beach sustainability assessment: The development and utility of an interdisciplinary approach to sandy beach monitoring. Journal of Coastal Research, 37(6), 1130-1157.

Steven, A., Addo, K. A., et al. (2023). Coastal development: Resilience, restoration and infrastructure requirements. In The blue compendium: From knowledge to action for a sustainable ocean economy (pp. 213-277). Cham: Springer International Publishing.

Aiswarya A, a fifth-year architecture student at Marian College of Architecture and Planning, is passionate about ecological sustainability in urban contexts. Her research explores the impact of rapid urbanisation on fragile ecosystems. She recently presented her work at Anveshan, the IIA International Research Conference.
Email: aiswu2k2@gmail.com

Ar. Ganga Krishnan (B.Arch., M.Arch.) is a professor at Marian College of Architecture and Planning, Thiruvananthapuram, landscape Architect, educator and researcher with over 18 years of experience. She is the honorary chairperson of ISOLA Kerala Chapter and is pursuing a PhD focused on blue-green infrastructure and lake restoration, bridging academia and practice for sustainable urban and ecological landscapes.
Email: ar.gangakrishnan@gmail.com

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala during 29-31 August 2024, under Stream II: The Significant Present

User Perception of Safety on Campus Open Spaces of Higher Educational Institutes

By Ar. Nupur Chichkhede

1. Introduction

In an effort to create a campus that is safe and secure, higher educational institutes, today face several problems. Although college campuses have long been thought of as safe havens for students, certain occurrences have forced administrators to face the task of becoming disaster ready. Additionally, mental health problems are becoming more common in society. The majority of previous and ongoing studies on campus safety lack a comprehensive viewpoint, despite the fact that this area of study is expanding (Jennings et al., 2007). This study examines the differences in users' perceptions of safety on HEI (Higher Educational Institute) campuses in Pune. It focuses on users' perceptions of their sense of safety in campus open spaces.

2. Literature Review: Theoretical background

Prior research has focused on the relationship between individual characteristics and a degree of safety, for instance, it is believed that gender is a significant and reliable determinant of safety perception (Gargiulo et al., 2020). Perceived safety can also be significantly influenced by one's own experience. Campus location can influence perceived safety from crime. Perceptions of safety can also be enhanced by maintaining the environment and well-maintained vegetation in the campus (Li et al., 2015). The presence of pedestrians, or natural surveillance, can significantly increase women's perceptions of safety. (Paydar et al., 2017). Also, because there is less supervision, dimly lit areas and hiding spots are major contributing factors to students' lower sense of safety in campus environments (Loewen et al., 1993). Additionally, campus security measures such as lighting and avoiding certain areas during the day are highly significant indicators of how safe students perceive their surroundings to be (Maier and DePrince, 2019).

3. Methodology

The study area comprises five higher educational campuses in Pune city. The campuses selected based on their location, scale, size, landscape elements, open spaces landscape characteristics features. The five prominent campuses identified as campus 1, campus 2, campus 3, campus 4, campus 5.

Campus 1 is spread over 33 acres of land. It is a beautifully landscaped Campus and imparts quality education to more than 15,000 students at any given point of time through its State-of-the-Art infrastructure and Ultra- modern amenities. There are 13 Institutions and One State Private University.

Campus 2 is a picturesque campus spanning 65 acres, with several magnificent Gothic-style structures. Campus 2's national nature is reflected in the makeup of its student and instructor body. It has also drawn a large number of international students. About 5,500 undergraduate and graduate students receive instruction in the natural sciences, computer science, electronics, information technology at the graduate and postgraduate levels, humanities, and social sciences at campus 2.

The area of Campus 3 is 36 acres. Due to the roads that separate them, the campus is separated into four sections. The College's current administration building serves as the primary structure. Campus 4 is spread across 85 acres. It houses 24 colleges of various disciplines major among them are the Medical College, Dental College and College of

Figure 1: Physical and Mental Health

Figure 2: Safe Movement: Pedestrian and Vehicular

Engineering Pune. This campus has a fully developed football and sports ground of 5 acres. It also houses hospitals, hostels, canteens, an ATM centre, bank, medical store, mess and other facilities. The campus is a well maintained, environment friendly green campus.

Spanning across 65 sprawling acres, in Campus 5, students with unparalleled experiential learning opportunities that seamlessly blend academic offerings with courses in Peace Studies, yoga and meditation. Students here get a diverse range of sporting opportunities, immersion programmes, internships and year-round on-campus events and cultural clubs all geared towards fostering the holistic development of the students.

All the five campuses were studied and mapped based on assessment components for landscape services such as provisioning services, Regulating Services, Socio Cultural Services, Information Services and sub services and indicators derived from theoretical framework (Abhijit and Nupur, 2021). The indicators of user perception on safety were lamp at walkway, park area, sitting area, shelter, entrance park border, simple mobility, CCTV availability, security and street lighting on pathways, visibility and openness within the surrounding.

Survey Tool

A questionnaire with 5 sections was prepared to collect information from 195 participants. The questions were based on the five types of services and the indicators were developed based on literature. Students, teaching and non-teaching staff participated voluntarily - which comprised a safety mapping page and a conventional survey about personal information and general questions about perceived safety. Participants were required to mark places such as daily activities and assessment components for the landscape services derived from campus open spaces which includes simple mobility, CCTV availability, security, and street lighting on pathways.

4. Data Analysis and Findings

Findings show that user perceived "safety" in higher educational campuses through Outdoor Recreational Areas, Easy Movement, Disabled-Friendly Infrastructure, Group Activity Spaces, Active Recreational Spaces. Feeling safe in the campuses is one the most valued variables derived.

5. Results and Discussion

- **Outdoor Recreational Spaces**

The outdoor recreational spaces are adequately active and cheerful on all five campuses.

- **Easy movement for persons with disability**

Easy movement for persons with disability on five different campuses differs significantly – from most difficult, to quite easy. Campus 2 has unique provisions in place that allow free movement around and function independently.

- **Group Activity Spaces**

All the five campuses provide for daily activities, like work and study setting. Outdoor spaces to work and study help to conduct group activity spaces effectively.

Figure 3: Friendliness and Community Building

Figure 4: Feeling Safe: Openness to Surrounding

- **Safe Movement: Pedestrian and Vehicular**

The campus users can move safely in the campus without the fear of vehicles on all campuses.

- **Feeling Safe**

All 5 campuses show feeling safe in campus outdoor spaces. The reasons could be the presence of security gates, CCTV cameras and openness within the surrounding.

- **Friendliness and Community Building**

Campus open spaces and the landscape have contributed in developing a sense of friendliness and community building among the campus users. The different landscape settings and design with social fulfilment also promote Place identity.

- **Physical and Mental Health**

All five campuses offer opportunities to relax, recover from stress while promoting health/enjoyment, walks, jogging, exercise etc. These contribute to improve physical and mental health of the users.

6. Conclusions and Recommendations

The aim of this study was to investigate university students' and staff's perceptions of "safety" in campus open spaces. A holistic perspective was taken, focusing on safety perceptions in places where crime and traffic accidents are expected.

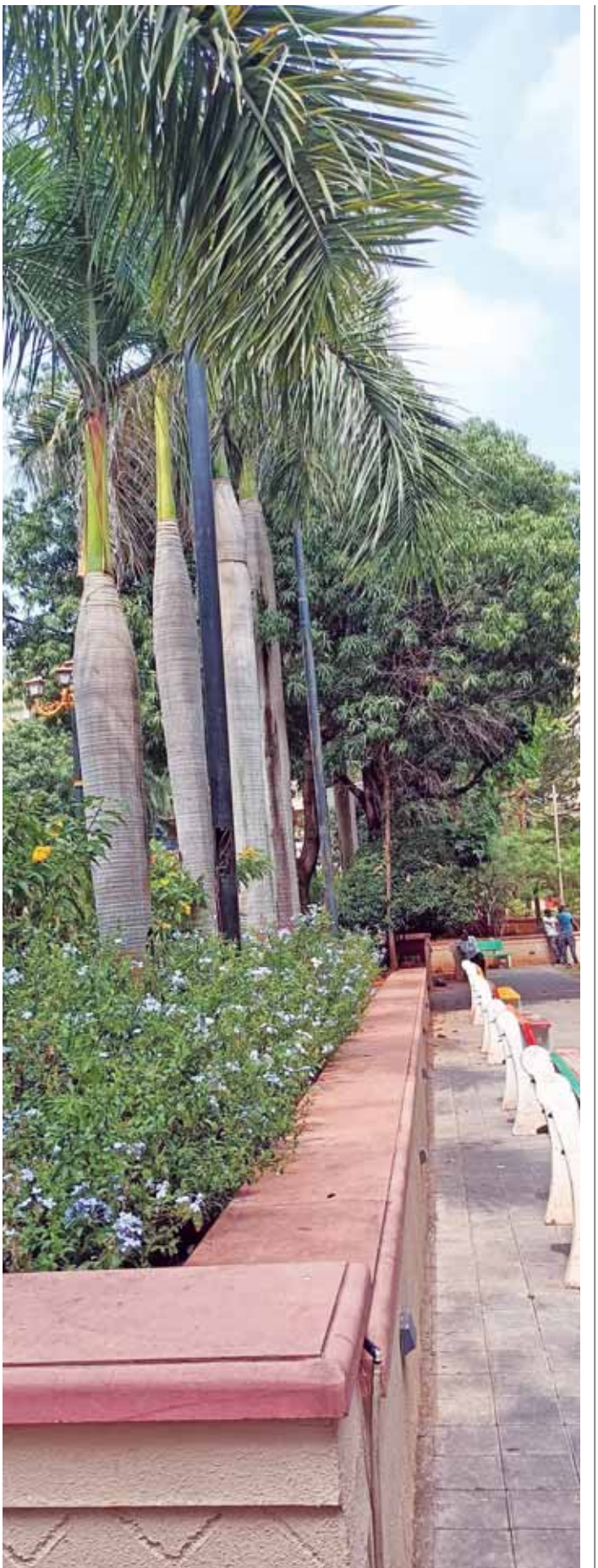


Figure 5: Seating and Relaxing Spaces

The study considers the nature of safety in terms of physical and mental health, focusing on ease of movement for people with disabilities as well as friendliness and community building. The study shows that students' perceptions of safety are influenced by lighting conditions, the presence of others, the installation of video surveillance systems, and mixed vehicular and pedestrian traffic, in addition to personal characteristics. "Safety" is a complex and multifaceted phenomenon, and environmental aspects must be taken into account when implementing security measures on campus.

All Photos credit: the Author

Nupur Chichkhede completed B.Arch in 2011 and Master's in Urban Planning in 2014. Currently, she is pursuing a Ph.D. Her academic career began in 2014 and now she is with Dr. D. Y. Patil College of Architecture, Akurdi, Pune, India. Her areas of specialisation and interests include Urban Planning, Environmental Planning, Ecosystem Services, and Landscape Services.

Ar. Chichkhede has co-authored and presented numerous research papers at national and international conferences, and her work has been published in refereed journals. She has been honored with the Young Professor Award at the Global Educational Awards and National Excellence Awards.

Email: nupurchichkhede@gmail.com

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, during 29-31 August 2024, under Stream 3: The Projected Future.

Capturing the Tacit Knowledge in Building Crafts from the Body Movements of the Craftsman

by Ar. Surya S. and Dr. Binumol Tom

Building crafts involve skilled use of tools by craftsmen who express their knowledge and techniques of local building culture through architecture. Traditional craftsmanship relies on local materials and culture, promoting sustainability. However, with advancements in building technology, traditional craftsmanship has declined, leading to the loss of knowledge and skills. Ensuring sustainability in building requires reviving this traditional knowledge. This study aims to understand the nature of knowledge required for traditional building crafts and develop a method to capture, store and transfer this knowledge to future generations. Traditional building crafts comprise both explicit (documented) and tacit (unspoken and unarticulated) knowledge. The research objectives are to differentiate these components, understand how craftsmen display tacit knowledge through skill, and devise a method to capture it. The research methodology employed in this study is qualitative and descriptive, utilising content analysis of tacit knowledge theories, supplemented by literature reviews and interviews with craftsmen. The research methodology employs hypothetic deductive method. The key findings in this research are that the tacit knowledge resides within the mind of the craftsman and craftsman's body movements while exercising a skill, reflecting the knowledge in his mind. This knowledge can be comprehended by observing and imitating these movements. The study proposes that if there is a method to capture the body movements of a master craftsman, along with his live explanations about what he is doing, then his tacit knowledge can be captured, stored and transferred to future generations.

1. Introduction

The venerable practice of traditional craftsmanship in building has consistently upheld principles of sustainability. The knowledge of traditional craftsmanship has traditionally been held by craftsmen and passed down from generation to generation. This encompasses both tacit and explicit forms of knowledge. However, with the rise of modern building technologies, the importance of traditional craftsmanship diminished. In the absence of an apprentice in the future generation, the tacit knowledge of the building craft, vested with the craftsman, dies away when the person passes away or retires. Recognising the significance of traditional craftsmanship knowledge, UNESCO and building craft researchers worldwide have endeavoured to conserve and safeguard this expertise (Karakul, 2018). While explicit aspects of this knowledge can be gleaned from canonical textbooks, capturing and preserving the tacit knowledge held by craftsmen presents a challenge. Various initiatives are underway to develop methods for capturing, conserving and transmitting tacit knowledge to future generations. This research aims to devise a methodology for capturing the knowledge inherent in traditional building carpentry practices, specifically focusing on roof construction within Kerala's traditional architecture. The extended objective of this research is to preserve the acquired knowledge in digital format, thereby ensuring its accessibility and usability for future generations.

1.1. Aim and Objectives

Kerala boasts of a rich architectural heritage, particularly in timber construction, exemplified by numerous palaces, religious buildings and residential

structures that highlight the exceptional skill of its carpenters and craftsmen. Despite the advent of modern technology leading to a decline in traditional craftsmanship, preserving this heritage is crucial as it symbolises cultural identity and demonstrates the craftsmen's high level of mastery and precision. These artisans adhere to principles from canonical textbooks for building dimensions, room placement, and other functional aspects, yet their actual construction skills are tacit, passed down through generations. The absence of apprentices necessitates capturing and preserving this tacit knowledge in a format from which it can be extracted and used by future generations. Capturing such knowledge is challenging, as apprentices typically spend months or years observing, imitating and learning from master craftsmen. During the execution of a craft, the artisan elucidates his actions to an observant apprentice, utilising specific terms from the local dialect within his explanations. The research aims to substantiate the hypothesis that the narration by a master and the observation of the master's bodily movements enable an enthusiastic observer to assimilate specific knowledge. This hypothesis will be examined through a series of literature-based case studies across various disciplines where bodily movements play a critical role in the transmission of tacit knowledge. By analysing these examples, the study seeks to elucidate the mechanisms through which embodied learning occurs, highlighting the interplay between verbal instruction and physical demonstration in the effective transfer of expertise. The objectives include distinguishing between explicit and tacit components of knowledge, understanding how tacit knowledge is transferred during direct apprenticeship, understanding the importance of the master's body movements in conveying tacit knowledge and devising a method to replicate this learning process digitally by capturing these body movements.

2. Methodology

The methodology employed in the study is qualitative and descriptive, and utilises a hypothetic- deductive approach in which literature studies underpin the research hypothesis and content analysis of literature as well as interviews with craftsmen. An extensive literature review has been conducted to study the theory of tacit knowledge to identify research gaps in capturing and transferring of tacit knowledge in traditional Kerala carpentry. Following the theory of tacit knowledge, a research hypothesis is formulated, suggesting that capturing body movements can indeed capture tacit knowledge. This hypothesis is tested through an analysis of cases where such capturing has been attempted, evaluating the methods used and identifying which methods may be suitable for capturing the tacit knowledge of Kerala's traditional timber craftsmen. Content analysis of literature case studies and interviews with craftsmen to validate the hypothesis is done. Upon successful validation, recommendations are provided on the best practices and methods for effectively capturing tacit knowledge in this specific context. Figure 1 shows the methodology flowchart.

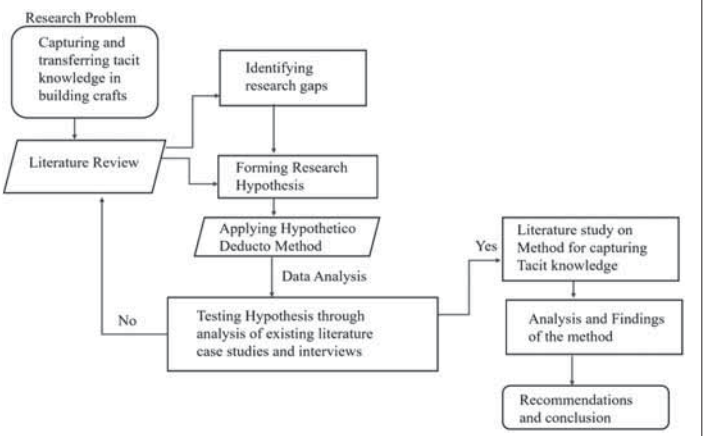


Figure 1: Methodology Flowchart
Source: Author

3. Literature Review

This research is conceptually founded on Polanyi's theory of Tacit Knowledge. Polanyi (2009) introduced the concept of tacit knowing, asserting that "we can know more than we can tell." Tacit knowledge is knowledge that cannot be articulated but is demonstrated and acquired through practice. Polanyi describes two aspects of tacit knowledge: proximal and distal. For instance, when recognising a face, we are aware of the face as a whole (distal) but not of the individual features (proximal). Similarly, in mastering a skill, the proximal involves the actions taken to perform the task, while the distal is the overall process. Polanyi illustrates this with the example of a blind man using a stick. Over time, the stick becomes an extension of his hand, allowing him to "feel" the tip without consciously knowing how. This tacit, bodily knowledge is internalised and cannot be easily expressed in words. For craftsmen, the tools they use become extensions of their bodies through practice. An apprentice learns by mentally and physically imitating the master craftsman's movements, internalising the pattern of their actions. This process involves understanding the skillful performance of another through comprehension and imitation. To understand another's knowledge, one must grasp their skillful bodily movements, as these are governed by the mind's knowledge. Thus, the mind and body together transfer tacit knowledge from master to apprentice.

Ojha (2020), in his study titled 'Digital Capture and Transfer of Tacit Knowledge Embedded in Craft Systems,' delves into the complexities of capturing and transferring the implicit knowledge inherent in craft objects. The research addresses three pivotal questions: identifying the components of tacit knowledge from live crafts and artifacts, isolating these tacit components, and programming this knowledge so that it can be utilised by design researchers to train new generations of craftspeople. Using Grounded Theory, Ojha meticulously documented craftsmen at work through photography and videography, supplemented by in-depth interviews to elucidate their tacit thinking processes. This approach led to the development of a fuzzy model that encapsulates the craftsman's knowledge, evaluating craft products based on design elements like colour, shape, pattern, size, and texture. Additionally, the study employed a transfer learning algorithm, an advanced AI technique, to extend craft knowledge. Despite its innovative approach, the research highlights a significant challenge: the complexity of the fuzzy model's computer language, which poses difficulties for designers. This approach highlights the challenge of creating a common, natural language between the designer and the computer and that the absence of such a language impedes information flow. The designer should not need to be a computer specialist or rely on a software engineer to translate their knowledge into a digital format. Therefore, one of the aims of the present research is to find a common language that allows the observer to effectively transfer the captured process of training from the master craftsman to the apprentice, facilitating the preservation and continuation of traditional craft knowledge. Another research gap identified from the aforementioned study is its focus on craft objects, while the proposed research is based on building crafts, specifically the timber architecture of Kerala. This distinction highlights the need to adapt and expand methodologies for capturing and transferring tacit knowledge from smaller craft objects to larger, more complex architectural practices. The timber architecture of Kerala, with its unique construction techniques and intricate craftsmanship, requires a tailored approach to document and digitise the skills and knowledge of master craftsmen in a way that preserves the architectural heritage and facilitates its transmission to future generations.

Høgseth (2012) explores the transmission of tacit knowledge and knowledge through action among craftsmen across generations. The creative process of craftsmen is fundamentally cognitive, involving initial decisions on the desired outcome and subsequent development of tools and procedures to achieve it. The concept of 'knowing how' pertains to the physical movements and technical skills of craftsmen, while 'knowing what' encompasses the reflective and intellectual aspects of these movements and techniques. Craftsmen integrate both forms of knowledge, with their bodily movements and perceptions playing a crucial role in their praxis, intricately intertwined with technical actions.

Transmission of knowledge through action emphasises learning through imitation and replication. This process involves sensory perception and communication through practical engagement. Attention in action facilitates the transfer of techniques, rhythms, energy and strength. Mastery of these techniques occurs through repetitive practice, combining physical and mental training until actions become automatic. As apprentices diligently imitate their masters' actions, they gradually incorporate their own style into the acquired knowledge, eventually achieving mastery themselves.

Wood et al. (2009) explain their study capturing the skills of Sheffield's traditional folding knife makers, now practiced by few craftsmen. An expert learner collaborated with these craftsmen under a designer's observation, leading to iterative making and prototyping sessions. These sessions produced learning materials which was later transformed into an online resource for contemporary metalworkers. The study revealed challenges in articulating tacit knowledge. Initially, craftsmen struggled to explain their techniques. For example, a craftsman, observing the learner's blade grinding, suggested a flatter angle using a mimed rocking motion, aiding the learner's understanding. This 'bridge' moment exemplified transferring tacit knowledge. These examples underscored the importance of such 'bridges' in facilitating the transmission of tacit knowledge from master craftsmen to novices, emphasising the role of interpretation and iterative refinement in capturing and conveying intricate craft skills effectively.

Chen, Y., & Zhang, D (2021) studied the creativity of craftsmen through embodied cognition. Integrating foundational research on narrative theory, their paper explores the interplay between embodied cognition, narrative ability and creativity in handicrafts. The findings suggest narrative functions as a form of embodied expression, and that creativity is enhanced as narrative ability improves. The study identifies four key elements of narrative ability: visual, meaning, bodily and consciousness. These elements aim to provide designers with a novel perspective on the creative processes and

creativity inherent in craftsmanship. The researchers identify that the expertise in handicraft increases with increasing narrative ability. At the same time, she (the craftsperson) demonstrates a state of "unity of mind and hand" in the process of craftsmanship. She can skillfully control materials and tools with her body". In this research, it becomes evident that, along with explaining their actions verbally, the gestures and movements of the craftspeople are equally significant.

The subsequent section of the literature review explores the timber architecture of Kerala and its significance. Koduveliparambil (1997) investigates construction practices in Kerala's traditional domestic architecture, highlighting the Vedic planning principles of Vasthushasthra and indigenous craft techniques. These Vedic principles were adapted contextually, and the craft techniques reflect early cross-cultural exchanges. Canonical texts such as Mahamanushyalaya Chandrika, Thanthra Samuchaya, Mayamatha and Shilparatna provide guidelines on dimensional systems for various structures, integrating religious beliefs to enforce traditional construction norms. Vasthuvidhya specifies structural member sizes and joinery details, emphasising the carpenter's skill, known as thatchushasthram in Kerala. Carpenters specialised in various domains, forming shilpashalas (craft- training schools) based on the master-disciple tradition. Apprentices began training around ages 10-12, learning through observation and practice. Techniques were taught within family workshops, integrating practical training with theoretical knowledge from texts like Thantrasamuchaya and Manushyalayachandrika. The most important part of the building was the roof and the carpenter skilled enough to work the roof precisely was considered a master craftsman. The ridge roof, pitched between 30 to 45 degrees, is a distinctive feature, adorned with carved gables and supported by wooden brackets, embodying Vasthushasthra's standardisation through modular geometry and precise dimensions. The roof's structural integrity relies on elements like the utharam (wall plate), upatula (floor joists), and tulopathula (bressummer), forming a strong space frame. Roof pitches of 45 degrees with eaves accommodate climatic needs. The wall plate anchors the roof to the top of the wall. Fixed atop the wall plate using wooden pegs is the secondary plate. The rafters slope down from the ridge and rest on this secondary plate. At the ridge, rafters from both slopes converge, connecting to a hanging beam called monthayam. As the rafters extend from the monthayam, they are radially arranged and secured to the koodam, an apex pinnacle. The rafters are evenly distributed on all four sides. Horizontal tie members are attached below the ridge, and a square-sectioned rod known as vala, or collar pin, is driven through holes in these members. This vala binds the rafters and tie beams, ensuring the triangular frame's stability and preventing displacement. Additionally, at the lower end of the rafters, pinning members provide further securement. Despite the considerable size and height of the roofs, the architectural emphasis remains predominantly horizontal rather than vertical. The roof, beyond its aesthetic prominence, represents the sthapathi's expertise in carpentry and mathematical precision. The pyramidal wooden frame system that forms the roof skeleton is a crucial component in the traditional architecture's overall construction process. In elaborate structures, intricate joinery and ornate engravings highlighted the precision and skill involved. Hardwood like teak and jackfruit were preferred for construction, with meticulous seasoning processes, ensuring quality. The master carpenter's design decisions, marked on wooden templates, guided the precise cutting and assembly of timber, blending explicit measurements with tacit craftsmanship learned through practice.

In this complex carpentry system, significant tacit knowledge is embedded. It is crucial to capture and transfer this knowledge to future generations, in the absence of a master craftsman. Literature studies and Polanyi's theory of tacit knowledge suggest that documenting the actions, body movements and gestures of craftsmen can facilitate this transfer. Thus, in examining the capture and transfer of craftsmen's tacit knowledge, the literature review has led to the hypotheses that (1) a craftsman's tacit knowledge is articulated through his bodily movements and the narratives he provides while performing the craft, and (2) developing a methodology to capture these movements alongside the narratives in a format amenable to digital storage and future retrieval can preserve the tacit knowledge inherent in traditional craftsmanship. The subsequent analysis section of this research examines case studies, exploring methods for capturing expert body movements, not only in crafts but also in other disciplines where embodied tacit knowledge is vital.

4. Data Analysis and Findings

As evidenced by the literature, actions and body movements significantly contribute to the demonstration of an expert's tacit knowledge alongside verbal narration. This part of the research explores various techniques employed by researchers to capture the body movements of experts to

encapsulate tacit knowledge. Different researchers have utilised diverse methods for recording these actions. While it is feasible to record narration to make such knowledge explicit, the documentation of body movements requires distinct methodologies. Video recordings and sketches have been identified as effective means of capturing these movements. Nevertheless, it is imperative to investigate whether more efficient techniques exist for capturing and storing body movements.

In her research, Nicola Wood (Wood, 2014) collaborated with timber craftsmen to generate video content of their craft for future learners. A central feature of this practice-led research was the use of video to document the practical knowledge of skilled craft practitioners, aiming to make it accessible to individuals interested in learning the skill. However, Wood presents the view that video is primarily beneficial for those who are already experienced in the craft. For beginners, videos proved to be a challenging medium for learning. Learners often struggled to relate the observed techniques to their own work. Wood's interpretation of this phenomenon is that for complex skills, a significant portion of the expert's knowledge is tacit. Consequently, a video tends to obscure rather than elucidate the practice. Expert practitioners make tasks appear easy, tacitly responding to subtle cues that may be kinesthetic, visual, auditory or olfactory in nature. While experts can verbalise some aspects of their skill, much of their knowledge remains unspoken. As a result, observers must interpret what they see and attempt to replicate it in their own practice, which is a difficult task for novices. In response to this challenge, Wood developed a multi-layered approach to interpreting the skills she had recorded. This approach uses interpretations based on images and text as a starting point for novices, providing a bridge across the knowledge gap between themselves and the experts. Video remained a valuable tool for disseminating research, particularly in creating multimedia outputs rather than paper-based documents for research projects.

Ho (2021) studied the craft of traditional woodblock printmaking in Japan, utilising this technique in film to explore tacit knowledge in relief print-making processes. This study aims to provide a counter-argument to Wood's "conceal rather than reveal" criticism. The primary research question addressed was, "how can movement in print-making be captured and conveyed to others through the specific medium of film?" In pursuit of this, Ho filmed herself engaged in the printing process, using various camera angles to display tacit knowledge. She paid close attention to subtle cues such as breath, pressure, speed of movement, and the posture of her entire body, striving to incorporate these elements into the film output. Upon the creation and screening of the film, the researcher concluded that constructed film, particularly with constructed sound, has the potential to appear unexpectedly realistic, engender phenomenological responses, and convey a richer understanding of tacit knowledge.

Anwar et al. (2011) suggested that the imagery of motor movements might play an important role in acquiring new motor skills. In their study, they utilised two groups of subjects who performed reaching movements either with or without motor imagery, defined as a dynamic state during which an individual mentally simulates a physical action. The group that performed movements with motor imagery exhibited higher after-effects and decreased muscle co-contraction compared to the no-motor imagery group. These results demonstrated a positive influence of motor imagery on the acquisition of new motor skills and suggested that motor learning can be effectively facilitated by mental practice.

Another project aimed at capturing the tacit knowledge of craftsmen by recording their actions is DistanceLab's HandMade. HandMade is a wearable recording device designed to document the actions of artisans from a first-person perspective. Recordings made with HandMade allow audience members to immerse themselves more deeply into the experiences of artists or craft-makers than is possible with typical videos. HandMade captures an immersive record of how individuals use their hands. The video is captured using a wearable technology that resembles an apron and contains a miniature video camera with a wide-angle lens. Audio is captured binaurally, using special microphones worn in the participant's ears to capture exactly what they hear during a recording session. When headphones are worn during playback, audience members experience a heightened sense of immersion, feeling as if they are "inside the head" of the subject. The point-of-view camera angle allows viewers to map hand movements more directly to their own bodies, enhancing their ability to learn these techniques in the absence of the subject.

The process of capturing and imitating the body movements of a master to transfer tacit knowledge extends far beyond the realm of traditional crafts. This method is invaluable in various fields where tacit knowledge is conveyed through physical actions, such as music, dance, sports, healthcare etc. Research on the idea that our perception of

music is not limited to just hearing the sounds but also involves understanding the physical actions that create those sounds prove that the visual auditory integration in music helps in associating specific sounds with corresponding actions (Kim, 2020). In sports, the REPLAY (Reusable Low-Cost Platform for Digitising and Preserving Traditional Participative Sports) project (Moran et al., 2013) exemplifies the use of motion capture technology to record expert athletes' movements. This data trains novices to replicate these movements, effectively transferring complex, implicit knowledge. The REPLAY project aims to preserve traditional sports by creating a "library of movement" using motion sensing technologies. Researchers spent three years collecting extensive data from GAA players using sensors and infrared cameras, preserving their traditional techniques. The project developed a cost-effective 3D sensor system using off-the-shelf technology, such as Microsoft Kinect and budget PCs, making advanced motion capture accessible to sports clubs across Europe.

Tan et al. (2019) explore innovative approaches to learning Intangible Cultural Heritage (ICH) through embodied interaction, focusing on traditional Cantonese porcelain crafting. This research developed a WebAR application that presents various processes through tangible interaction with virtual porcelain represented by physical objects. Learners can directly interact with these objects, bridging tangible materials and making processes of ICH through WebAR. Empirical studies indicate that WebAR and embodied interaction enhance students' tangible learning experiences, facilitating knowledge transfer between craftsmen and students. As Flanagan & Fraietta (2019) denote - "On macro and micro scales, mobility determines design due to the geographical accessibility of the communities where data is to be collected and on the micro-scale the craft traditions demand that the method of capturing data does not impede freedom of movement of hand gestures". This is one advantage of wearable device.

Analysis

Methods to capture tacit knowledge include video and audio recordings, although some studies suggest this method is inadequate for inexperienced beginners. Enhanced video techniques, such as capturing from different angles, zooming in, and adjusting playback speed, have shown more promise. Image-processing, including the use of explanatory sketches, can sometimes effectively capture and transfer gestures. However, capturing videos and images can make the expert self-conscious, potentially affecting the authenticity of their actions. Alternatively, wearable technology, such as gloves or sensors, can capture motion without making the expert overly conscious, although this requires expertise in wearable tech and can be expensive. Motion capture technology is another option, though it may not be affordable for all contexts. Creating a library of captured movements can also be an effective method. Interviews and discussions were conducted with traditional Kerala craftsmen. Maniyasari, a master craftsman hailing from Etumanoor in Kerala, and whose familial lineage is intricately linked to the works of the Perumbalam Temple, currently supervises a cohort of forty-two apprentices and junior carpenters. He asserted that his profound expertise in traditional carpentry was derived from canonical texts such as the Thantrasamuchaya. His perspectives on apprenticeship corroborated findings in existing literature, as identified in the researcher's studies. On questioning about capturing the craftsmen's methods in video he revealed specific challenges, particularly due to the large size of the materials (large timber members) and the need for both wide and close-up shots to capture the intricacies of tool use. This is especially true while working with timber members in roof construction of Kerala traditional architecture. This opens the scope future research in which documentation of the process of erecting a Kerala roof, the activities involved in it and the instructions given by the master craftsman to his apprentices might reveal suitable and adequate methods for capturing the tacit knowledge.

A combined approach, integrating video capture, audio narration, detailed images, and wearable motion capture devices, might offer a comprehensive solution. However, this method's feasibility is limited by cost and the required expertise. Literature also highlights the necessity of a 'common language' to facilitate the transfer of captured data to the computer and ensure the apprentice can easily access and understand it. This is particularly challenging with the aforementioned methods, except for the more straightforward video capture method.

5. Results and Discussion

The hypothesis formed after the literature review posits that a craftsman's tacit knowledge is articulated through his bodily movements and the narratives he provides while performing the craft. Developing a methodology to capture these movements alongside the narratives in a format suitable for digital storage and future retrieval can preserve the tacit knowledge inherent in traditional craftsmanship. This hypothesis was analysed through case studies and interviews, and the results confirmed its validity. However, the

methods to capture these movements are still in experimental stages, and various methods currently in use could be improved to develop a technique that allows for motion and audio capture, modeling, transfer, and elicitation in a more inexpensive, effective, and simpler manner.

6. Conclusions and Recommendations

Traditional craftsmanship embodies invaluable tacit knowledge, which must be transmitted to future generations to ensure its preservation. In the absence of apprentices, capturing and storing this tacit knowledge for future retrieval becomes imperative. This research aims to identify a method by which the tacit knowledge embedded in Kerala's traditional timber carpentry can be effectively captured.

A review of literature on tacit knowledge theories suggests that documenting the body movements of craftsmen while they perform their skills can serve as a viable method for capturing tacit knowledge. Various methods for recording body movements across different contexts and skills were analysed, including video and audio recordings, image capturing, motion capture technology, and wearable devices. The research concluded that a hybrid approach, integrating these diverse methods, should be developed to be both user-friendly and cost-effective.

This study highlights the potential for future research to refine existing methods, making them more efficient, simpler and economical. It is recommended that further investigation and documentation of Kerala's traditional craftsmen, specifically during the process of roof erection, be conducted. Understanding how craftsmen utilise their body movements to impart knowledge to their apprentices is crucial for devising an effective method to capture these movements.

References

Anwar, M. N., Tomi, N., & Ito, K. (2011). Motor imagery facilitates force field learning. *Brain research*, *1395*, 21-29.

Chen, Y., & Zhang, D. (2021) Body and Narrative: A Study on The Creativity of Craftsman from the Perspective of Embodied Cognition.

Flanagan, P. J., & Fraietta, A. (2019, September). Tracing the intangible: the curious gestures of crafts' cultural heritage. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers* (pp. 49-52).

Ho, W. G. (2021). Three observations on filming tactility and movement in crafts-based practice: A preliminary investigation. *FormAkademisk*, *14*(2).

Høgseth, H. B. (2012). Knowledge transfer: The craftsmen's abstraction. *Archaeology and Apprenticeship: Body knowledge, identity, and communities of practice*, 61-78.

Karakul, Ö. (2018). An Integrated Approach to the Conservation Of Traditional Biılding Crafts And Their Sustainability in Contemporary Design. *CRAFTARCH*, *18*, 5-7.

Kim, J. H. (2020). From the Body Image to the Body Schema, From the Proximal to the Distal.

Koduveliparambil, J. J. (1997). Construction Practices in Traditional Dwellings of Kerala. *India, School of Architecture McGill University*.

Moran, K., DCU, A. A., Ugalde, M. D., GAA, M. J. D. A., Unzueta, L., & Linaza, M. T. (2013). Reusable low-cost platform for digitising and preserving traditional participative sports.

Ojha, S. P. (2020). *Digital capture and transfer of tacit knowledge embedded in craft objects* (Doctoral dissertation).

Polanyi, M. (2009). The tacit dimension. In *Knowledge in organisations* (pp. 135-146). Routledge.

Tan, P., Ji, Y., Hills, D., & Fu, T. (2019). Bridging knowledge between craftsman and learner in Chinese intangible cultural heritage through WebAR. In *SIGGRAPH ASIA art gallery/art papers* (pp. 1-5).

Wood, N. (2014). Silent witness, using video to record and transmit tacit knowledge in creative practices.

Wood, N., Rust, C., & Horne, G. (2009). A tacit understanding: The designer's role in capturing and passing on the skilled knowledge of master craftsmen. *International Journal of Design*, *3*(3).

Surya S is an Associate Professor of Architecture at Government Engineering College, Thrissur, Kerala, with expertise in sustainable design, landscape architecture and history of architecture. With over two decades of academic and professional experience, she has published widely. She is also actively involved in curriculum development, consultancy and architectural research.
Email: arsuryas@gmail.com

Dr Binumol Tom is a Professor of Architecture at Rajiv Gandhi Institute of Technology, Kottayam, Kerala. She holds a PhD in conservation of timber and has excellent knowledge of sustainable design and history of architecture. She has authored several research papers, articles and book chapters. She is the AICTE nominee to Council of Architecture and is actively involved in consultancy and architectural research.
Email: binumoltom@gmail.com

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, during 29-31 August 2024, under Stream 2: The Significant Present

Exploring the Role of Open Space in Shaping the Social Fabric of Community

By Shantanu Chitgopkar

1.1 Introduction

Open space is an integral part of built environment. Provision of open space is mandated by the building byelaws. They are being provided in the form of setbacks, green spaces, tot-lots, driveways, etc. (MoUD, 2016) to provide the basic ventilation and light to the building inside. Buildings built without setbacks will lack sufficient sunlight or ventilation. At urban or town level, URDPFI (‘***Urban and Regional Development Plans Formulation and Implementation Guidelines)*** recommend an area of 10 to 12 sq. m per person as desirable open space. These are provided in the form of parks, playgrounds, maidans, etc. (MoUD, 2015). Parks or green urban spaces are termed as green infrastructure which provide the necessary lung space for fresh air (Valente et al., 2020) and as buffer space for acoustical and against environmental pollutions (Xie et al., 2020).

1.1 Social Fabric

Social fabric can be explained as the cooperation and relationships among the residents of a community (He et al., 2023). It supports the satisfaction and mindfulness, belongingness, trust and mental health of the of the community residents, thereby building the social cohesion in the community. Desolation or loneliness can affect the mental health and wellbeing of the members of the community and infuse distrust, which can affect the social fabric. The recent social isolation due to COVID-19 was a good example of it.

Community engagement through various activities in the open space provides the necessary reasons for people to gather and share their ideas and thoughts. space for activities which promotes physical health and mental wellbeing. It also supports nature connectedness thereby improving the empathy towards nature. Recreational activities have been widely researched to understand its usability, benefits and characteristics. Non-provision of place for collective activities like well-maintained green open space, can erode social fabric, giving rise to higher insecurities (Ayala-Azcárraga et al., 2019).

1.2 Open Space

Open space is defined as a space blocked by trees, built space, etc. they are like a park, garden, etc. in an urban area. A space open to the sky, forming a part of the site, designated by local body authority (BIS, 2016). It is provided as per the population and area of the community. It is an open space not covered by building structures or vehicles, or an empty land earmarked for building in the future (Alidoust & Bosman, 2015). It is also the space and light above the open space land (Lay, 2003). It is a space for visual delight, action, and instinctive activities (Koohsari et al., 2015). It is a place for collaborative activities and social interaction, which lead to social cohesion (van Herzele & de Vries, 2012a; Peschardt et al., 2012). It is a place for rest and restitution, for the people on the way to work or home (Peschardt et al., 2012). Social gatherings, common activities, interaction among users, in the open space, promote a sense of belonging (Woolley, 2003; Gehl, 1987). The usage of open space fosters place attachment, which promotes social cohesion (Sia et al., 2020)

1.3 Aim and Objectives

The aim of this study is to review the existing literature on the open space and its role in fostering social fabric in a community. The objective is to study about open space and its benefits, understand its features and their effects and study the role of open space in shaping the social fabric. Open spaces like agricultural farmlands, forest areas, open areas left for services, open parking areas, etc. are beyond the scope of this study. It is limited to open spaces available in the form of parks, green space, recreational space, all in residential neighbourhoods.

2. Methodology

A keyword search was done in Scopus to select peer-reviewed papers. The Boolean operator 'OR' was used for the keyword open space and related keywords. It was also used for keyword social fabric and related words. Boolean operator 'AND' was used between these two groups. Through backward and forward references, a few more studies were identified. Selected papers were further screened and a conference paper, editorials, dissertations, papers under irrelevant categories like biology, neuroscience, energy, animals, etc. were excluded. Out of 277 papers, which were the outcome of keyword search, 30 studies were selected for review, based on the relevance of paper.

3. Literature Review

Characteristics of Open Space can be broadly grouped into nature, spatial, activities, safety and amenities. Nature based characteristics are vegetation, trees, shrubs, grass, rocks, waterbody, etc. Spatial characteristics are size, location, accessibility, distance, etc. The popularity of open space is based on its characteristics, which includes it location, size, safety, cleanliness, amenities, space for activities, lawns, etc.

3.1 Spatial characteristics

Open spaces like parks, works as destination to where persons can walk and do casual physical activities. Pleasant green space has positive effect on the walking activity, but a large size of open space, even though not so pleasant, had affected in increased walking activity and also physical activity (Sugiyama & Ward Thompson, 2008). Physical aspects of green space like size, type, layout, distance to park, affect the perception of the green space. Which in turn affects the usage and then social cohesion (Wan et al., 2021). The size of the green area provides the option of a large gathering space for activities, bringing people together for a longer time, thereby increasing the chance of social trust and improving social cohesion (Kaczynski et al., 2008).

During the study done by Cristina Ayala-Azcárraga and others, the participants preferred visiting the parks located within the neighbourhood were regularly even though it was small in size. Visit to larger parks was less frequent but were also visited by people from other neighbourhood. Distance to open space has effect on the frequency of the visitations (Ayala-Azcárraga et al., 2019). Spatial publicness, a feature of open spaces, is right to have public life and build communities, and is associated with the accessibility, functionality and connectivity of open spaces (Zhang et al., 2024)

3.2 Nature as characteristics

Amount of green space and its quality like diversity of spaces with-in, clean environment, well maintained and pleasant arrangement have a strong connection with social cohesion and stress (De Vries et al., 2013). The absence of facilities in the green space may reduce the usage of parks and thereby reduce the chance of social interaction, which will impact social cohesion (Wan et al., 2021). Daily greenspace exposure primarily helps to improve participants' mental wellness and reduce their depressive feelings. It fosters social haleness and boost social cohesion, improves bodily health and reduce chances of diseases to a minimal (L. Zhang et al., 2018). Tranquility of the space, Landscape beauty and diversity, Presence of a water element, etc. were the preferred characteristics of open space. The common characteristic is the perception of health and well-being associated with green space (Pinto et al., 2021).

Children when exposed to greenness within their neighborhood, have positive effect on the development of cognitive development, which relates to their IQ (Lee et al., 2021). In older adults, higher association with greenness has shown slower cognitive decline (de Keijzer et al., 2018). Older adults have been greatly benefitted by the urban green space for their physical and mental health. Activities in this space keep them healthy (Axmon et al., 2024). It is also related to longevity among older adults (Ji et al., 2019). Pleasant green space with absence of nuisance and well laid walking path, is related to the increased walking time (Björk, 2019).

Tree cover, an indicator for measuring greenness, have an inverse relationship with open space visitation. It may be due to the perception as unsafe space, due to increased vegetation. But has more

footfall from nature lovers (Shanahan et al., 2015). Type of vegetation, its density, upkeep and design has effect on the safety perception of open space. Sparse vegetation with open landscape design attribute have positive effects on perceived safety (Jansson et al., 2013). Positive perception increases visitation of peoples, thereby effects social ties.

3.3 Infrastructural characteristics

Other than the spatial characteristics like accessibility, size, distance to, and presence of greenery, which effects the perception and visitation, the infrastructure or the attributes of open space support the engagement of user with the open space. Public open space acts as venue for social interaction among senior citizens, which is mediated by neighborhood social cohesion. It mitigates the isolation that many experience after retirement or losing a friend or companion. Place attachment, commonly defined as people-place bonding in which individuals acquire unique sentiments and emotions for a certain geographic area, can emerge when elderly individuals experience a sense of connection to and dependence on their place of residence (Chen et al., 2022a).

The availability of toilets, coffee shops, gym equipment, are few of the major utility contributors of open space, thereby increasing the visitation and social interactions (Grilli et al., 2020). Provision of a proper pathway to open space and conducive facilities within open space, supports active physical activities like walking and social connect (Sugiyama & Ward Thompson, 2008). Infrastructural characteristics drives the users age group. Sports facilities attracts active teenagers for paying and social networking. Lawns and landforms attract young children. Shaded walkways, seating attracts older adults (Kabisch & Kraemer, 2020). Many activities like picnic, reading, resting, chatting, are observed in places where seating facilities are provided. It is also the place for group of people to come together (Schmidt et al., 2019). Older adults find these place attractive, as they feel safe and part of community, and not alone or socially isolated (Pleson et al., 2014). Vast green open spaces, provides place for different age groups to have various activities simultaneously like playing, gathering, resting, etc. (Ayala-Azcárraga et al., 2019).

Upkeep of open space is also a parameter for effective usage of open space. An unclean and ill-maintained green space will inhibit users from visiting or spending less time in the space. The presence of physical characters which are not directly visible or not well illuminated gives rise to safety concerns (Wan et al., 2021). Presence of walking trails, illumination, exercise equipment, cleanliness, seats and safety features, were determinants for usage of open space (Ayala-Azcárraga et al., 2019).

4. Discussion and Conclusions.

The open space in a built environment is widely studied and documented. The ecosystem service is provided by the open space in the form of carbon sink, lung space, eco balance, etc. (Brink et al., 2016). The open space also provides for different age group or cultural group, to come together and know each other (Ayala-Azcárraga et al., 2019). The presence of nature in the form of lawns, bushes, water bodies, trees, fosters nature connectedness and also elevates the mental well-being (Pinto et al., 2021; Chitgopkar et al., 2020). An open space with well-maintained and diverse spaces, has a positive effect on social cohesion and stress reduction (van Herzele & de Vries, 2012b). but an unmaintained open space gives perception of unsafe place and deters people visitation (Wan et al., 2021). A dense vegetation and perception of noxious fauna makes the open space feel unsafe (Jansson et al., 2013). Absence of illumination, security persons or cameras, presence of strays, are the safety concerns, which have effect on the visitation and use of open space.

The accessibility of open space has direct relationship with the frequency of visits (Alcock et al., 2020). Availability of infrastructure like well-laid walking trails, impacts the health of users, and promotes social interaction while walking. Seating facility and shaded walkways, accessibility to space, attracts older adults and make them socially connected to their neighbours (Chen et al., 2022b). Presence of space for diverse activities in open space and engagement of users, has effect on the time spent in open space (Grilli et al., 2020). The size of seamless space like lawns, allows users to spend quality time by playing, picnicking, or have a community event. This bring people together and know each other, thereby strengthening the social fabric, which enhances social cohesion.

For an open space to mediate as social connect, it shall be accessible, within the reasonable distance from neighborhood and has enough size and shape to accommodate the diverse user groups requirement. To keep people, engage, it shall have the infrastructure like walking trails, seatings, age appropriate playing areas, and amenities like toilets and equipment. A well designed, landscaped open space, improves the aesthetic value of the open space and helps in place attachment, which in turn effects social fabric. An open space with diverse features to accommodate various social, cultural and age groups,

helps inclusivity in the society. The greenness of open space fosters nature connect, improves mental wellness and provides space physical activities. It improves the wellness and social interaction among the users and thereby strengthens the social fabric of the community. Further studies can be done in effect of climatic conditions or geographical conditions, has effect on the usage pattern of social space.

Cited References

Alcock, I., White, M. P., Pahl, S., Duarte-Davidson, R., & Fleming, L. E. (2020). Associations between pro-environmental behaviour and neighbourhood nature, nature visit frequency and nature appreciation: Evidence from a nationally representative survey in England. *Environment International*, *136*. https://doi.org/10.1016/j.envint.2019.105441

Alidoust, S., & Bosman, C. (2015). Planning for an ageing population: links between social health, neighbourhood environment and the elderly. *Australian Planner*, *52*(3), 177–186. https://doi.org/10.1080/07293682.2015.1034145

Axmon, A., Mattisson, K., Lethin, C., Fänge, A. M., Carlsson, G., & Stroh, E. (2024). Access to urban green spaces and use of social services and institutional long-term care among older people in Malmö, Sweden: a longitudinal register study. *BMC Geriatrics*, *24*(1). https://doi.org/10.1186/s12877-024- 05112-z

Ayala-Azcárraga, C., Diaz, D., Zambrano, L., Ayala-Azcarraga, C., Diaz, D., Zambrano, L., Ayala-Azcárraga, C., Diaz, D., & Zambrano, L. (2019). Characteristics of urban parks and their relation to user well-being. *Landscape and Urban Planning*, *189*(February), 27–35. https://doi.org/10.1016/j.landurbplan.2019.04.005

BIS. (2016). National Building Code of India, 2016 Volume 1. *National Building Code of India*, *80*, 1 v. (various pagings).

Björk, A. (2019). Reconsidering critical appraisal in social work: choice, care and organization in real-time treatment decisions. *Nordic Social Work Research*, *9*(1), 42–54. https://doi.org/10.1080/2156857X.2018.1475299

Brink, E., Aalders, T., Ádám, D., Feller, R., Henselek, Y., Hoffmann, A., Ibe, K., Matthey-Doret, A., Meyer, M., Negrut, N. L., Abson, D. J., & Wamsler, C. (2016). Cascades of green: A review of ecosystem- based adaptation in urban areas. *Global Environmental Change*, *36*, 111–123. https://doi.org/10.1016/j.gloenvcha.2015.11.003

Chen, S., Sun, Y., & Seo, B. K. (2022a). The Effects of Public Open Space on Older People's Well-Being: From Neighborhood Social Cohesion to Place Dependence. *International Journal of Environmental Research and Public Health*, *19*(23). https://doi.org/10.3390/ijerph192316170

Chen, S., Sun, Y., & Seo, B. K. (2022b). The Effects of Public Open Space on Older People's Well-Being: From Neighborhood Social Cohesion to Place Dependence. *International Journal of Environmental Research and Public Health*, *19*(23). https://doi.org/10.3390/ijerph192316170

Chitgopkar, S., Dash, S. P., & Walimbe, S. (2020). Gated Community Living: A study of contemporary residential development approach in Indian Cities. *PalArch's Journal of Archaeology of Egypt/Egyptology*, *17*(9), 7437–7451.

de Keijzer, C., Tonne, C., Basagaña, X., Valentín, A., Singh-Manoux, A., Alonso, J., Antó, J. M., Nieuwenhuijsen, M. J., Sunyer, J., & Dadvand, P. (2018). Residential surrounding greenness and cognitive decline: A 10-year follow-up of the whitehall II cohort. *Environmental Health Perspectives*, *126*(7). https://doi.org/10.1289/EHP2875

De Vries, S., van Dillen, S. M. E., Groenewegen, P. P., & Spreeuwenberg, P. (2013). Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Social Science and Medicine*, *94*, 26–33. https://doi.org/10.1016/j.socscimed.2013.06.030

Grilli, G., Mohan, G., & Curtis, J. (2020). Public park attributes, park visits, and associated health status.

Landscape and Urban Planning, *199*. https://doi.org/10.1016/j.landurbplan.2020.103814

He, B., Gilligan, J. M., & Camp, J. V. (2023). An index of social fabric for assessing community vulnerability to natural hazards: Model development and analysis of uncertainty and sensitivity. *International Journal of Disaster Risk Reduction*, *96*. https://doi.org/10.1016/j.ijdrr.2023.103913

Jansson, M., Fors, H., Lindgren, T., & Wiström, B. (2013). Perceived personal safety in relation to urban woodland vegetation - A review. *Urban Forestry and Urban Greening*, *12*(2), 127–133. https://doi.org/10.1016/j.ufug.2013.01.005

Ji, J. S., Zhu, A., Bai, C., Wu, C.-D., Yan, L., Tang, S., Zeng, Y., & James, P. (2019). Residential greenness and mortality in oldest-old women and men in China: a longitudinal cohort study. *The Lancet Planetary Health*, *3*(1), e17–e25. https://doi.org/10.1016/S2542-5196(18)30264-X

Kabisch, N., & Kraemer, R. (2020). Physical activity patterns in two differently characterised urban parks under conditions of summer heat. *Environmental Science and Policy*, *107*, 56–65. https://doi.org/10.1016/j.envsci.2020.02.008

Kaczynski, A. T., Potwarka, L. R., & Saelens P, B. E. (2008). Association of park size, distance, and features with physical activity in neighborhood parks. *American Journal of Public Health*, *98*(8), 1451–1456. https://doi.org/10.2105/AJPH.2007.129064

Koohsari, M. J., Mavoa, S., Villianueva, K., Sugiyama, T., Badland, H., Kaczynski, A. T., Owen, N., & Giles- Corti, B. (2015). Public open space, physical activity, urban design and public health: Concepts, methods and research agenda. *Health and Place*, *33*, 75–82. https://doi.org/10.1016/j.healthplace.2015.02.009

Lee, K. S., Choi, Y. J., Cho, J. W., Moon, S. J., Lim, Y. H., Kim, J.

I., Lee, Y. A., Shin, C. H., Kim, B. N., & Hong, Y. C. (2021). Children's greenness exposure and iq-associated dna methylation: A prospective cohort study. *International Journal of Environmental Research and Public Health*, *18*(14). https://doi.org/10.3390/IJERPH18147429

MoUD. (2015). *URBAN AND REGIONAL DEVELOPMENT PLANS FORMULATION AND IMPLEMENTATION (URDPFI) GUIDELINES*.

MoUD. (2016). *Model Building Bye-Laws*. https://www.ptonline.com/articles/how-to-get-better-mfi- results

Peschardt, K. K. K. K., Schipperijn, J., & Stigsdotter, U. K. K. U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). *Urban Forestry and Urban Greening*, *11*(3), 235–244. https://doi.org/10.1016/j.ufug.2012.04.002

Pinto, L., Ferreira, C. S. S., & Pereira, P. (2021). Environmental and socioeconomic factors influencing the use of urban green spaces in Coimbra (Portugal). *Science of the Total Environment*, *792*(PG-), 148293. https://doi.org/10.1016/j.scitotenv.2021.148293

Pleson, E., Nieuwendyk, L. M. L. M., Lee, K. K. K. K., Chaddah, A., Nykiforuk, C. I. J. C. I. J., & Schopflocher,

D. (2014). Understanding older adults' usage of community green spaces in Taipei, Taiwan. *International Journal of Environmental Research and Public Health*, *11*(2), 1444–1464. https://doi.org/10.3390/ijerph110201444

Schmidt, T., Kerr, J., & Schipperijn, J. (2019). Associations between neighborhood open space features and walking and social interaction in older adults-a mixed methods study. *Geriatrics (Switzerland)*, *4*(3). https://doi.org/10.3390/geriatrics4030041

Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2015). What is the role of trees and remnant vegetation in attracting people to urban parks? *Landscape Ecology*, *30*(1), 153–165. https://doi.org/10.1007/s10980-014-0113-0

Sia, A., Kua, E. H., & Ho, R. (2020). Building Social Resilience Through Parks and Common Recreational Spaces. In *Advances in 21st Century Human Settlements*. Springer Singapore. https://doi.org/10.1007/978-981-13-7048-9_4

Sugiyama, T., & Ward Thompson, C. (2008). Associations between characteristics of neighbourhood open space and older people's walking. *Urban Forestry and Urban Greening*, *7*(1), 41–51. https://doi.org/10.1016/j.ufug.2007.12.002

Valente, D., Pasimeni, M. R., & Petrosillo, I. (2020). The role of green infrastructures in Italian cities by linking natural and social capital. *Ecological Indicators*, *108*. https://doi.org/10.1016/j.ecolind.2019.105694

van Herzele, A., & de Vries, S. (2012a). Linking green space to health: a comparative study of two urban neighbourhoods in Ghent, Belgium. *POPULATION AND ENVIRONMENT*, *34*(2), 171–193. https://doi.org/10.1007/s11111-011-0153-1

van Herzele, A., & de Vries, S. (2012b). Linking green space to health: A comparative study of two urban neighbourhoods in Ghent, Belgium. *Population and Environment*, *34*(2), 171–193. https://doi.org/10.1007/s11111-011-0153-1

Wan, C., Shen, G. Q., & Choi, S. (2021). Underlying relationships between public urban green spaces and social cohesion: A systematic literature review. In *City, Culture and Society* (Vol. 24). Elsevier Ltd. https://doi.org/10.1016/j.ccs.2021.100383

Woolley, Helen. (2003). *Urban open spaces*. 194.

Xie, J., Luo, S., Furuya, K., & Sun, D. (2020). Urban parks as green buffers during the COVID-19 pandemic.

Sustainability (Switzerland), *12*(17). https://doi.org/10.3390/SU12176751

Zhang, C., Zhang, N., Zhu, P., Qin, S., & Zhang, Y. (2024). The Evolution and Driving Mechanisms of the Blue-Green Space Publicness Pattern in Changsha, China. *Land*, *13*(4). https://doi.org/10.3390/land13040403

Zhang, L., Kwan, M. P., Chen, F., Lin, R., & Zhou, S. (2018). Impacts of individual daily greenspace exposure on health based on individual activity space and structural equation modeling. *International Journal of Environmental Research and Public Health*, *15*(10). https://doi.org/10.3390/IJERPH15102323

Shantanu Chitgopkar (A12836) is an Additional Professor at Manipal School of Architecture and Planning, with over 14 years in professional practice and 11 years in academia, his work bridges theory and architectural practice. He is currently pursuing a PhD under Dr. H. H. Shinde (MGMU) and Dr. Rama Devi Nandineni (MSAP).
Email: shantanu.c@manipal.edu

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala, during 29-31 August 2024, under Stream 3: The Projected Future

The Critical Review of Environmental Impacts of River Development
A Case Study of Mumbai

By Pornima Anil Buddhivant

1. Introduction

Water forms the essential commodity of life by playing a complex and multifaceted role in human activities and natural systems (Siddiqui A., Agarwal D., Gupta A., & Yunus M., 2004). Similarly, urban waterfronts have evolved into vibrant centres of recreation, tourism, and commercial activity which, serve as gathering places for social, cultural, and religious gatherings in the modern cities. During the industrial era, the riverside development aimed to improve the financial status and image of the neighbouring towns. (Simons S., Kinjawadekar A., & Kinjawadekar T., 2023).

Rivers hold significant economic, environmental, and cultural value in India. The significance of the river landscape in society has always developed to fulfill humans' ever-changing demands (Adlay I., Gupta P., 2018). As globalisation and industrialisation accelerate, the country has several issues in supplying clean and safe drinking water to the population. When a river flows through a city, we always assume its banks and encroach by adjusting its flood line. In other countries, the river serves as a foreground, but in India, it has always been looked it as background. It is important to use the river as a foreground when riverfront land is examined critically. A river is initially more than just an urban stream, later polluted by industrial waste and sewage (Santana, 2022). Urbanisation has led to environmental degradation, and cities looking for maximum developable land expansion has begun to build on banks along natural watercourses. This has destroyed water quality, destroyed biodiversity, and created negative polluted social spaces. The principal causes of pollution are untreated sewage and industrial wastewater; however, non-point pollution sources from agricultural and livestock, religious activities, and poor solid waste management contribute considerably to pollution (NGRBA).

According to the Ministry of Environment and Forest (MoEF), Government of India, an Environmental Impact Assessment (EIA) is required before beginning any large development project as it is an important management technique for ensuring the best use of natural resources for long-term development (Water Resources Department, Maharashtra, 2011). The major criteria of the assessment should maximise economic returns, and it should be technically feasible to decide the desirability or even the viability of the project. It is now widely recognised that the development effort may frequently produce not only sought benefits but unanticipated-undesirable consequences as well, which may nullify the socio-economic benefits for which the project is designed (Dr. S. Maudgal, IELRC). It is important to deal with the development of a methodological procedure for the identification, analysis and assessment of the risks arising from construction work and related activities relative to the legal requirements for environmental impact assessment.

1.1.1 Aim

To identify, analyse, and review the environmental impact of development projects along the Mumbai Rivers for the decision-making to endorse secure and environmentally friendly development.

1.1.2 Objectives

- To understand the existing condition of the Mumbai rivers.
- To explore the causes and sources of water pollution in Mumbai rivers
- To analyse the impacts of water pollution on rivers in Mumbai
- To assess the impact of river development on the existing status of the flora and fauna
- To analyse the increased flood risks associated with river development projects and provide solutions to improve their current condition

1.1.3 Statement of the Problem

The rapid urbanisation and industrialisation of Mumbai have resulted in substantial alterations in the city's natural landscape, particularly on its river systems. Rivers such as the Mithi, Dahisar, Poisar, and Oshiwara have undergone extensive development which include the construction of embankments, real estate projects, industrial establishments, and waste disposal systems. These developments have had a significant environmental impact which impact water quality, biodiversity, and the overall health of the ecosystem.

1.1.4 Research Problem

The central problem investigation is the environmental impact of river development in Mumbai, which will be done through case studies. This research challenge is essential because it addresses the following major issues:

1. Water Quality Degradation: Development projects along Mumbai's rivers have increased pollution levels from untreated industrial effluents, sewage, and garbage. This degradation causes serious threats to public health and the aq uatic ecology.
2. Loss of Biodiversity: Mumbai's River development is destroying habitats for flora and fauna. This loss of biodiversity can disturb the ecological equilibrium and impair the ecosystem's resilience to environmental change.
3. Increased Flood Risk: Urbanisation and change of river systems can lead to more frequent and severe flooding events. This not only results in economic losses, but it also puts human lives and city property at risk.
4. 4. Socioeconomic Impacts: Riverbank communities are typically disproportionately affected by development activities. Changes in these river habitats cause displacement, loss of livelihoods, and restrict access to the clean water which have an influence on the region's socioeconomic fabric.

1.1.5 Research Gap

The research gap of the river development projects in Mumbai, specifically concerning environmental impact of the cumulative effects on local biodiversity, hydrology, and the socio-economic dynamics of adjacent communities.

1.1.6 Scope & Limitations

The study will focus on rivers within the administrative limits of Mumbai, India, that includes major and minor rivers identified by local authorities. The sampling frame will include a comprehensive list of all identified rivers. The limitation of the study are all river development projects; the seasonal changes will serve as the primary units of observation.

2. Literature Review

The Stockholm conference in 1972 raised global awareness of the environmental consequences of unplanned development (Mather A S & Chapman K, 1995). The International Association for Impact Assessment (IAIA) was founded in 1980 as an important global policymaking forum for EIA. Furthermore, the UN Summit on Environment and Development (UNCED), often known as the 1992 Rio de Janeiro Convention, introduced the concept of sustainable development by including EIA documentation as a pre-planning requirement (UNCED, 1992). The world's major countries have agreed to implement the Environmental Impact Assessment (EIA) to identify the environmental impact of human activities on each significant project (Nadir H. & Ahmed A., 2023). Planning authorities typically recognise EIA as an evaluation technique for anticipating, recognising, and mitigating the environmental impacts of megaprojects, enabling long-term development with minimal environmental consequences (LawTeacher, 2013).

Water conservancy projects, also known as water projects which are built by controlling and deploying various water resources in the natural world to eliminate harm and benefit (Rehman, 2017). River

waterfronts have the potential to become the recreational and cultural hubs of the city and have emerged as lively urban faces. River development also has the potential to create Environmental Awareness for the cleanliness of the river and generate ecological awareness and tourism for the river edge, thus preventing the disposal of untreated sewage into the river, but at the same time, the natural geographical characteristics of rivers are also changing, and the ecological service function of rivers and the ecological environment of river basins are heavily damaged (NGRBA). Water projects are often built at the expense of other resources. Studies by Kondolf G. (2020), highlight the need for a balanced approach that considers ecological sustainability alongside urban development.

The Metropolitan City of Greater Mumbai has seen tremendous growth in population over the last few decades. A comprehensive analysis of the expected and other potential impacts on various environmental and population components, such as water, soil, air, climate, flora, and fauna, along with landscape, cultural, and historical monuments, forms the basis of an environmental impact assessment (Centre for Science and Environment). On 26 July 2005, Mumbai floods affected many parts of Mumbai as can be seen in Figure 1. On this day, the city received 944 millimeters of rain, a percentage of the season's average, out of a 100- year high. Much of the city is built on land reclaimed from low-lying marshes in the 19th century, not just tides but causing devastating floods in the city. In the emerge disaster, electricity, water supply, interconnected networks, and public transport were completely shut down; 1493 people died and more than 14,000 houses were destroyed. In the backdrop of haphazard urbanisation, this event had a great impact on Mumbai (Joshi P., 2016).

Figure 1: Mumbai floods, July 2005
Source: Pankaj Joshi, The Hindu

Adapting urban planning to future hydrological changes in a sustainable manner is a major task because of the complex and context-specific processes of cities which are associated with large uncertainties (Pathak S., Liu M., Jato-Espino D., Zevenbergen C., 2020). Moreover, understanding urban hydrology is challenged by its inherent complexity and the dynamic interactions between river and drainage networks. The feedback information provides support for the new project decision-making management, as well as has important scientific value and practical significance (Zhi-qi Zhou, 2019). The EIA study presents the environmental baseline status of the project area, the identification of major environmental impacts, the prediction of various impacts during and after the proposed developmental activities, the evaluation of these impacts, followed by suggestions for an effective environmental management plan to minimise the adverse impacts (Water Resources Department, Government of Maharashtra, 2011).

3. Methodology

The methodology used in this study on the environmental impact review of river development in Mumbai highlights a systematic approach to studying and evaluating the effects of human activities on river ecosystems.

3.1 Data Collection:

The study begins with an extensive literature review of global and local river development projects that focus on environmental impact research and policy documents. This is followed by a detailed case study analysis of specific river development initiatives in Mumbai by examining their objectives, implementation processes, and reported outcomes. The quantitative primary data collection involves photographic surveys to assess water quality, soil health, and biodiversity along the affected riverbanks. The qualitative secondary data will be gathered from academic journals, government reports, official documents and relevant literature.

3.2 Data Analysis:

The collected data will be used to analyse project locations and impacts. The study will begin with a systematic review of existing literature to establish a foundational understanding of the river development projects in Mumbai and their documented environmental impacts. Data synthesis will focus on comparing findings from various reports and studies. This analysis will be supported by mapping to visualise changes in river ecosystems and urban development patterns. The critical review will culminate in

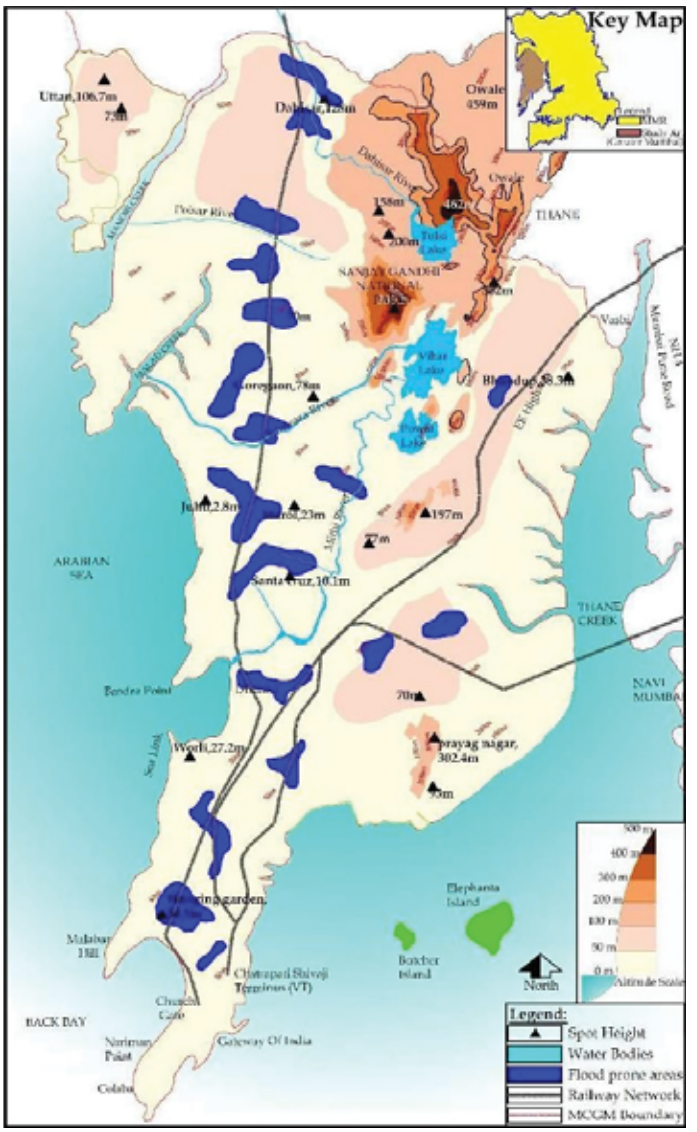


Figure 2: Landforms, waterbodies and flood-prone areas, Greater Mumbai

Source: Gaurkhede N., Adane V., Khonde S., 2021

formulating insights and recommendations based on the aggregated evidence by aiming to provide a comprehensive understanding of the long-term environmental consequences of river development in Mumbai.

4. Data Analysis and Findings

4.1 Causes and Sources of Water Pollution

There are various causes of water pollution in the rivers. These causes can be divided into two broad divisions, namely:

a) Natural causes: The biodegradable components of plants and animals mix with water to contaminate it. Erosion of river banks causes siltation, which can harm aquatic life. Many natural salts and other substances mix with rainwater and ultimately discharge into rivers and ponds.

b) Man-made causes: Man-made pollutants include industrial, agricultural, and domestic waste, as well as excessive use of fertiliser, pesticides, and other pollutants. These pollutants contaminate the water significantly. Water polluted with such pollutants is extremely harmful to both human and aquatic life.

4.2 Sources of Pollution

The main sources of water pollution include untreated industrial wastes, solid wastes from urban and commercial areas, municipal sewage wastes, animal faeces, pesticides, fertilisers, radioactive wastes, erosion of lands and river banks, etc. Oil from industries pollutes the water in Maharashtra's rivers.

4.3 The main pollutants

a) Liquid Organic Wastes: Sewage, an industrial waste, and runoff from storms, floods, and rain are examples of liquid organic wastes. These materials are carried off the land and end up in streams, rivers, lakes, or oceans. Fish and aquatic plant life suffer or even died when the concentration of dissolved oxygen falls. BOD levels in some Mumbai rivers range from 15 to 150 mg/l (MPCB, Mumbai).

b) Liquid Inorganic wastes: Industry produces a large amount of inorganic liquid waste, which can be safely diluted in rivers. Some inorganic toxic waste can accumulate in the food chain that eventually affecting fish. Many of the pollution incidents that have resulted in many deaths and serious injuries from water pollution have been caused by humans consuming fish which are contaminated with heavy metals or other inorganic substances.

c) Micro-organisms/Germs: Animal faeces, sewage waste, and latrines can transmit bacteria, viruses, and other organisms into water bodies, causing pollution.

d) Nutrient substances: Domestic contaminants, surplus fertilisers, and minerals containing nitrate are mixed with water. These nutritional compounds stimulate the rapid development of unexpected plants, and decaying these plants gives water an unpleasant taste and odour. The abnormal growth of aquatic plants is known as 'eutrophication'.

e) Synthetic compounds: Synthetic compounds include cleaning agents, soaps, detergents, pesticides and other chemicals. Industries also release similar chemicals.

f) Inorganic chemicals: Inorganic pollutants include metals such as lead, zinc, cadmium, mercury, and arsenic, as well as their compounds. This group includes a large number of salts.

g) Silt and sediment: Soil erosion produces silt and sediment in water bodies. Construction activities caused soil erosion to increase by almost 100 times.

4.4 Impacts of water pollution

a) Impacts of Shortage of DO: Chemical reactions from industrial wastes depletes the DO levels. Plants absorb only about 40% of the dissolved urea. The balance is combined with water. It resulted in the rapid growth of unexpected plants. These plants' biodegradation requires oxygen from water. As a result, the concentration of dissolved oxygen (DO) is reduced.

b) Impacts of pH: There is no universal pH for all fish. Fish grow in ponds, rivers, lakes, and oceans with varying pH levels. However, abrupt pH shifts can be harmful and fatal to fish. During the dry season, the DO level drops significantly, and the river becomes highly toxic.

c) Impacts of trace elements/ions: Pollutants such as arsenic, lead, mercury, cadmium, chromium, nitrates, and nitrites can mix with water or produce. However, exceeding the limits of these trace elements can produce a variety of problems that affects humans and other living beings.

d) Impacts of germs/micro-organisms: People living near contaminated rivers frequently experience diseases such as cholera, diarrhoea, and dysentery.

e) Impacts of silts: Silt can cover aquatic leaves and increase water turbidity by preventing sunlight from reaching the plants' leaves and affecting photosynthesis. As a result, plants are unable to produce oxygen or food for themselves.

4.5 Study area

4.5.1 Introduction to site

The four major rivers of Mumbai i.e. Mithi River, Oshiwara River, Dahisar River & Poisar river form the rich heritage of Mumbai, but it also has a vast and intricate network of canals that flow through the city-like veins in the human body. These drains are important as they connect the rivers of Bombay and act as their tributaries or distributaries. However, over time, Mumbai's drains and rivers have become open drains filled with disease vectors that prefer open spaces for solid waste disposal (Sansare D., Mhaske S., 2020). It is believed that over 40% of the city's untreated sewage runs into rivers and streams. Another big issue with Mumbai's rivers, which is encouraged or neglected by government officials, is encroachment on the river banks. It is important to note that these people are not the only slum residents (Ravindran S., 2014). The Mithi River has also seen planned constructions such as the Bandra-Kurla complex.

4.5.2 Existing condition of Mumbai Rivers

A. Mithi River

Mithi River flows from the overflow of Vihar Lake (made by the British circa 1860 to supply drinking water to Mumbai) within the Sanjay Gandhi National Park (SGNP), and it also receives overflow from Powai Lake some 2 kilometres later (Jamwal N., 2018). The river flows seasonally and increases during the monsoons. It flows over 18 km before reaching the Arabian Sea at Mahim Creek, which passes through industrial and residential areas including Powai, Saki Naka, Kurla, Kalina, Vakola, Bandra-Kurla, Dharavi, and Mahim (see Figure 3). The river has an average length of 5 meters in its upper stages. It has been enlarged to 25 meters in the centre portion and up to 70 meters in the lower sections following the downpour on July 26. As per the study of the Maharashtra Pollution Control Board (MPCB) found the water at the mouth of the Mithi river and Versova beach to be the dirtiest, with pollution levels almost 13 times above the safe limit, as seen in Figure 4.

Figure 3: Mithi River
Source: Rivers in Mumbai, Me Mumbai

Figure 4: Untreated Surface runoff and storm water is released directly in the Mithi River
Source: Hindustan Times

B. Dahisar River

The Dahisar River begins in Tulsi Lake within the SGNP and flows through the north-west suburbs of Sri Krishna Nagar, Daulatnagar, Kandar Pada, Sanjay Nagar, and Dahisar Gaothan before joining the Arabian Sea through Dahisar Gaothan and meeting the sea at Manori Creek after 12 kilometres (Figure 5). The overall catchment area of the Dahisar River is 3,488 ha, with 24 percent of it built up (Jamwal N., 2018). Crocodiles inhabited the river until the late 1960s. The river has been polluted by the discharge of industrial effluents from workshops, as well as storm water and sewage from slums that flow into it. It has recently dropped and become shallower as a result of silt, garbage, and plastic bags accumulating. The rivers of Mumbai along with Dahisar river is been neglected and systematically destroyed, they have become dumping grounds for solid waste by all.

Figure 5: Dahisar River
Source: Rivers in Mumbai, Me Mumbai

C. Oshiwara River

The Oshiwara River (also known as the Walbhat River) flows from the Aarey Colony near SGNP, through the Goregaon hills, and into the Malad Creek after seven kilometers. Along the way, it meets another creek near Swami Vivekanand Road, which is then used to collect industrial waste and sewage while passing through Oshiwara. It has a catchment area of 2,938 hectares, 53 per cent of which is developed, with slums accounting for 23 per cent (Jamwal N., 2018). The length of Mumbai's sewer systems is around 1,973 km, but it excludes the informal and slum settlements, where half of the city's population lives (Figure 6). As a result, untreated sewage, industrial waste, and other pollutants from these areas drain into the local nullahs, where they enter rivers and

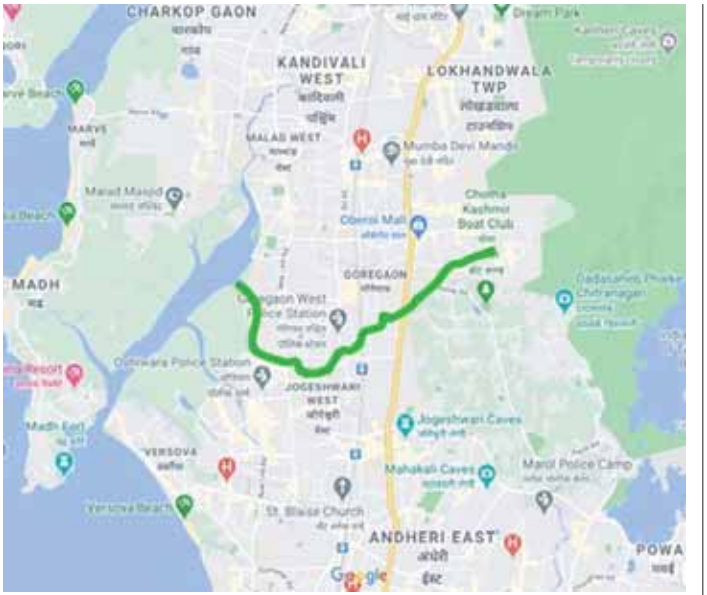


Figure 6: Oshiwara River
Source: Rivers in Mumbai, Me Mumbai

eventually end up in the sea. Ideally, these rivers should only transport runoff/stormwater and remain dry during the rest of the months (Sen A., 2024).

D. Poisar River

The Poisar (Poinsar) River originates in the SGNP as well and travels approximately seven km before coming to a stop at Marve Creek (Figure 7). Nearly 53% of its watershed was already developed as of 2005 (Jamwal N., 2018). The Poisar River flooded in 2005 during the catastrophic rains that hit Mumbai; the water damaged a tank and swamped the banks of a building site. The corporation is responsible for building for maintaining, and cleaning the city's drainage system by the MCGM Act of 1888. The

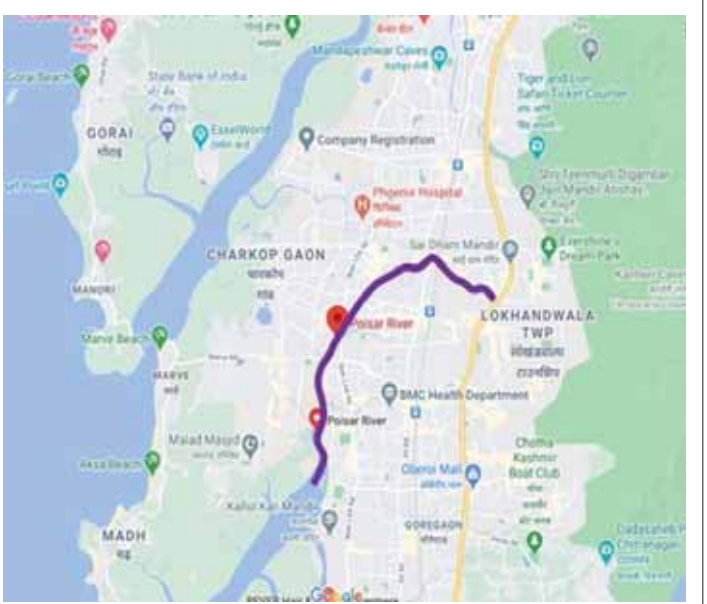


Figure 7: Poisar River
Source: Rivers in Mumbai, Me Mumbai

organisation is responsible for making sure the city has two distinct systems for disposing of waste and draining stormwater. Also, neither should mix up. In actuality, though, Mumbai's rivers serve as nothing more than conduits for raw sewage to be dumped into creeks and the ocean. In April 2017, volunteers of River March removed 1.47 lakh kg of garbage from a stretch of Poisar river. A 2016 report by the Environmental Policy and Research India (EPRI) had found that pollution levels in Poisar were 100 times more than the safe limit (Hindustan Times, 2017).

5. Results and Discussion

5.1 Degradation of Ecology

The polluted tide had washed up on the beaches near the river mouth, and the area's abundant mangroves began to degrade gradually. By 2015, it was predicted that Mumbai had lost about 40% of its mangroves from the 1980s, totaling 38,000 square kilometres (See Figure 8).

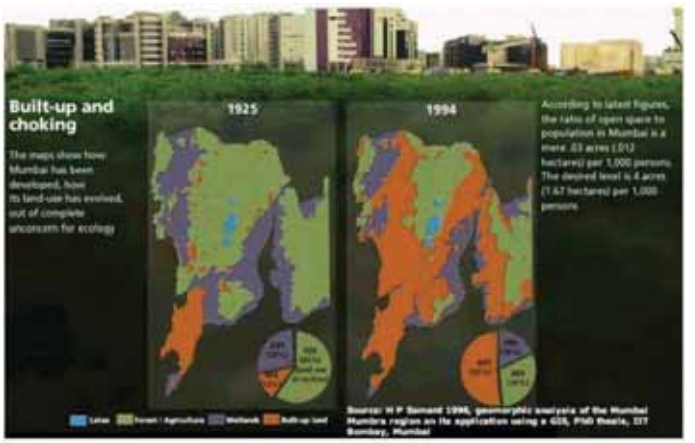


Figure 8: Geomorphic analysis of the Mumbai region
Source: Mumbai strategies to revitalie the rivers' urban corridors (May 2024)

6. Conclusions and Recommendations

This study examines the rivers of Mumbai and investigates how river basins and riparian land might be regenerated to create substantial spaces for the natural flow of rivers while maintaining the availability of public open land to make river restoration initiatives financially viable. Many of Mumbai's aquatic plants and animals rely on these rivers and streams for habitat, therefore their importance goes much beyond that of a basic sewer drain. Sewers are interconnected bodies of water, such as rivers and streams, that constitute a city's natural ecology as they deteriorate over time. Rivers have a direct connection to their floodplains and catchments. Creating concrete constructions that cut them off from their floodplains is a questionable way to kill the rivers. Flooding in their area has worsened

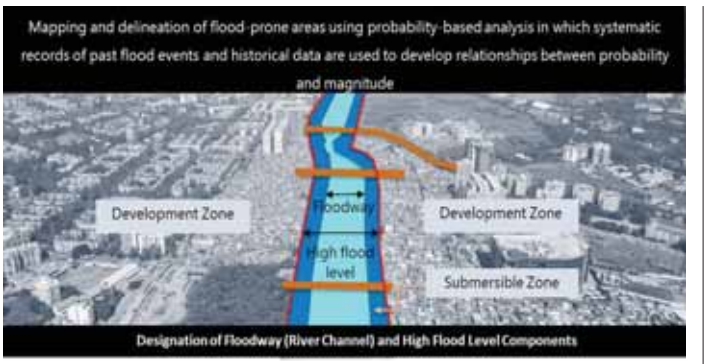


Figure 9: Mapping & Delineation of flood prone area, Mithi River
Source: Johnnie Miller, Behance (Edited map image)

since excess run-off cannot enter the nullahs and rivers.

The research recommendations are that the research could inform regional policies in Mumbai concerning river development that suggests guidelines for sustainable practices and environmental conservation. Insights from the study could contribute to national-level policies on river management and urban sustainability by influencing legislation and governance frameworks. The research may introduce innovative methodologies for conducting Environmental Impact Assessments (EIA) specifically made for river development projects in Mumbai. This could include integrating Geographic Information System (GIS) data with ecological assessments or developing new metrics for assessing aquatic biodiversity impacts. By critically analysing the environmental impacts of river development, the research could contribute theoretical frameworks to the field of environmental science and urban planning. This might include theories on sustainable urban development, resilience of urban ecosystems, or socio-ecological systems dynamics.

Cited References

Siddiqui A., Agarwal D., Gupta A., & Yunus M., (2004). Environmental Impact Assessment of River Valley Projects: Scientific Positions, Issues and Practice. Challenges in Sustainable Development. pp. 136-165. DOI: 10.13140/RG.2.2.30298.54726

Simons S., Kinjawadekar A., Kinjawadekar T., (2023). Assessing the impacts of ecological framework of Indian riverfront revitalisation projects. Environment, Development and Sustainability. DOI: https://doi.org/10.1007/s10668-023-03771-3

Adlay I., Gupta P., (2018). Yamuna River Project: New Delhi Urban Ecology September 2018, New York & Barcelona, ACTAR Publishers, 2018, 392 pp., 826. ISBN: 978-1-945150-67-8. DOI: 10.1080/18626033.2019.1673597

Nadir H., & Ahmed A., (2023). The Critical Review of the Efficacy of the Environmental Impact Assessment (EIA) Process as a Tool Intended to Protect the Environment from Construction/ Development's Hasards. Journal of Civil Engineering Research & Technology, 5 (2). pp. 1-7. ISSN: 2754-4982. DOI: https://doi.org/10.47363/JCERT/2023(5)143

Kondolf G. (2020). The Fit of Urban Waterfront Interventions: Matters of Size, Money and Function. May 2020 Sustainability 12(10):4079. DOI:10.3390/su12104079

Pathak S., Liu M., Jato-Espino D., Zevenbergen C., (2020). Social, economic and environmental assessment of urban sub-catchment flood risks using a multi-criteria approach: A case study in Mumbai City, India. Journal of Hydrology, Volume 591, December 2020. DOI: https://doi.org/10.1016/j.jhydrol.2020.125216

Zhi-qi Zhou, (2019). Study on the Index System of Environmental Impact Assessment (EIA) of Water Conservancy Projects. Nature Environment and Pollution Technology an International Quarterly Scientific Journal. Vol. 18, No. 5 (Special Issue), pp. 1561-1565, ISSN: 0972-6268

Gaurkhede N., Adane V., Khonde s, (2021). Identification of Interruptions in Urban Drainage Systems and Their Sustainable Solutions for Alleviating Flood Risk in Mumbai, an Indian Megacity. IDRiM (2021) 11 (1). ISSN: 2185-8322. DOI10.5595/001c.30705

Sansare D., Mhaske S., (2020). Natural hazard assessment and mapping using remote sensing and QGIS tools for Mumbai city, India, Research Gate, February 2020. DOI:10.1007/s11069-019-03852-5

Rehman, (2017). Water Conservation Projects: Best Practices and Lessons Learned, Acevips, April 26, 2023

Sen A. (2024) Oshiwara River, Mumbai strategies to revitalie the rivers urban corridors. May 2024. Department of city & regional planning, University of California, Berkeley

Santana, Famous Rivers in Mumbai, April 17, 2022. https://mumbai7.com/rivers-in-mumbai/?expand_ article=1

Mather A S, Chapman K (1995) Environmental Resources. ISBN 9780582101685 by Routledge. Megacity - Wikipedia (2023) https://en.wikipedia.org/wiki/Megacity.

UNCED (1992) The United Nations Conference on Environment and Development https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.1 51_26_Vol.I_Declaration.pdf

LawTeacher (2013). The main problems of Environmental Impact Assessment (EIA) https://www.lawteacher.net/free-law-essays/ international law/the-main-problems-of-environmental- impact-assessment-international-law-essay.php?vref=1.

Centre for Science and Environment. https://www.cseindia.org/understanding-eia-383

Joshi P., (2016). Remember the 2005 floods? Can we prevent it happening again?. The Hindu (July 10, 2016)

Ravindran S., Mumbai will likely flood again – and nobody's doing much about it, The Guardian, November 27, 2014. https://www.theguardian.com/cities/2014/nov/27/mumbai-flood-rain-monsoon-city-planning

Jamwal N., Anthems alone don't save rivers: Treat sewage & create room for the rivers, South Asia Network on Dams, Rivers and People (SANDRP), March 8, 2018. https://sandrp.in/2018/03/08/anthems-alone-dont-save-rivers-treat-sewage-create-room-for-the-rivers/

Chatterjee B., Mumbai group spends 5 Sundays clearing 1.47-lakh kg garbage from Poisar river (2017). Hindustan Times, Jun 24, 2017. https://www.hindustantimes.com/mumbai-news/mumbai-group-spends-5-sundays-clearing- 1-47-lakh-kg-garbage-from-poisar-river/story-J98he3jDVCUSd0vNsXKI5H.html

Environmental Impact Assessment Study for Ganga River Front Development at Patna, National Ganga River Basin Authority (NGRBA).

Environmental Impact Assessment for the Construction of Uma Barrage Across the River Uma near Village Borta in Tahsil Murtizapur (March 2011), Dist.

Akola, Maharashtra, Water Resources Department, Government of Maharashtra

Guidelines for environmental impact assessment of river valley projects, International Environmental Law Research Centre, Department of Environment, Ministry of Environment and Forests, January, 1985. http://www.ielrc.org/content/c8503.pdf

Comprehensive study/ profiling of mithi river, Maharashtra Pollution Control Board (MPCB), Mumbai

Ar. Pornima Buddhivant (A27373) graduated from the Rachna Sansad's Academy of Architecture, Mumbai, and pursued M. Arch. (Environmental) from BNCA, Pune. She is fueled by a profound love for teaching, which she does at Thakur School of Architecture & Planning, Mumbai. She is associated as a reviewer for Solar Decathlon India's student competition and research conferences. She is a TEDx Speaker, SDG advocate, and the founder of an Art Group called 'Karv Sankalan'.
Email: pornima.buddhivant7@gmail.com

ARTICLE

This article was presented at the IIA ANVESHAN Research Conference held at MCAP, Thiruvananthapuram, Kerala during 29-31 August 2024, under Stream II -The Significant Present

A Water-saving and Hybrid Multi-Purpose Shower and Drainage System for Residential Bathroom System

By Ar. Mueen Haris

Introduction

Shortage of water is rapidly growing to be a major issue of the current times both in rural and urban areas. Though this issue cannot be resolved on an individual level, mindful and efficient use of the existing water resources are the need of the hour for each one of us. Among the ways to deal with this, the most important is to study the way water is being consumed in our day-to-day activities and to optimise the same. The "three R's" of sustainability: reduce, reuse and recycle is a great way to move ahead in this direction.

Reduce: to use fewer resources in the first place. It takes resources to manufacture, transport, and dispose of products, so reduction minimises the use of new resources.

Reuse: Use materials more than once in their original form instead of throwing them away after each use. Reuse keeps new resources from being used for a while longer, and old resources from entering the waste stream.

Recycle: Converting waste materials into new products, changing them from their original form by physical and chemical processes. Although recycling uses energy, it helps to prevent new resources from being used and old materials from entering the waste stream.

The goal of the three R's is to prevent waste and conserve natural resources and resource optimisation. Among the aforementioned points in case of water management, reusing water in daily life is a sustainable way to save water.

Therefore, methods of reusing and saving water are becoming more and more desirable.

To overcome the disadvantages of the existing solutions, the presented invention provides an efficient unit which provides the feature of saving water while meeting the requirements of luxury. The following are the objectives:

- To provide the feature of saving water while meeting the requirements of luxury
- To provide a system which provides functional integrity
- To optimise the overall bathroom experience

In order to achieve the above objects, the technical scheme adopted by the presented invention is to provide an integrated water-saving intelligent bathroom system which comprises a merged space including a shower area, a toilet area, a usable balcony area and a sewage area. The shower system comprises a multi-mode of bathing including the mist cleanse mode which provides the feature of saving water while meeting the requirements of luxury.

While taking a shower for the purpose of bathing, we generally go through three stages, which includes wetting the body, lather the body and scrubbing with soap, and finally rinsing the body with water again to wash off the soap and dirt. The first step of wetting the body with water consumes almost equal amount of water as the last step of rinsing the body after soaping, which is not required. The only purpose of the first step is to moisten the body well enough to enable the soap application. There is no need for pouring a continuous steam of water on the body during that step which leads to unnecessary wastage of water in the drain. To avoid this wastage, the invention provides a cleanse mist mode in the shower. The mist mode enables the user to wet their body well enough by providing enough moisture for soap application without letting a stream of water run on the body. Additionally, the mist mode allows the provision to maintain to set a custom water temperature without allowing the body to dry in the process. This feature of creating a micro climate provides further comfort to the user while giving a luxurious bath feel.

Details

The approach of the design has been to assess the fundamental paradigm of shower bathing and segregation of utilised water and then establish a system that facilitates the same while saving water and maintaining high standards of luxury. The process of bathing can be largely divided into three parts - rinse, cleanse and wash. Rinse is essentially the step where the user wets the body and prepares it for the application of cleansers such as soaps and shampoo. The next step, as mentioned before, is the application of cleansers and then the final step, washing off the lather from the body. Considering the aforementioned steps as the general paradigm for bathing, the proposed design emulates and manipulates to create luxury, convenience and water saving methodologies.

The system comprises of a multi-mode switch control giving the user to choose from three different modes of shower bathing, namely, rinse, mist(cleanse) and wash, the switches are also connected to an actuator which is connected to a 2-way drain with segregated outlets for clear water and grey water. The actuator helps in opening and closing of the drain, allowing for segregation of water.

The three modes here emulate the general bathing paradigm however, the second step, which is the mist mode has a slight modification. Generally, while applying soaps or shampoo, people tend to keep the shower running as it helps in maintaining

Figure 1: Illustrates a perspective view of multi-mode shower according to the present invention
Source: Author

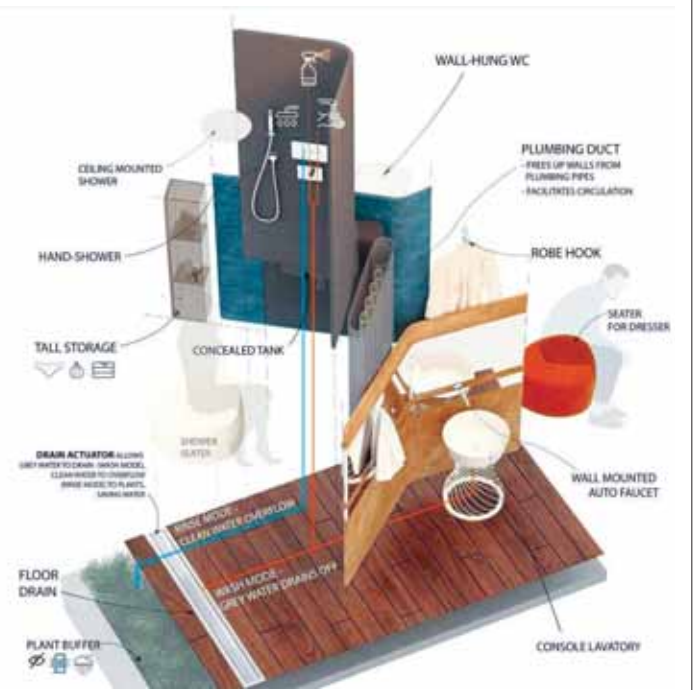


Figure 2: Illustrates a perspective view of showering apparatus according to the present invention
Source: Author

a comfortable temperature of the user, while switching it off brings down the temperature and thus becoming uncomfortable for the user. This habit results in sizeable wastage of water. The design aims at resolving this issue by introducing the mist option, which can be achieved by fitting an atomizer within the shower. The atomizer can be a mechanical or an electrical device that helps in atomizing or reducing the size of the water droplets and turning

them to mist. The mechanical component uses water pressure and smaller holes to achieve the mist, while the electrical one, creates sound waves, which creates rapid compression and rarefaction, due to which the water droplets cannot sustain their liquid state and get converted into water vapor immediately. The aim of the mist mode is to create a micro-climate around the user by keeping the temperature constant and also help in keeping the body optimally damp for the application of cleansers while negating the requirement for constant flow of water from the shower. The atomizer consumes less amount of water since it converts large droplets to smaller ones, this process saves water as well.

Connected to the multi-mode switch is the actuator and the 2-way drain. The idea here is segregate and re-purpose water. The concept in this design is that in the rinse mode, the water is used generally for wetting the body. No chemicals from soap and shampoos are involved thus leading to the supposition that the used water in this case can be re-purposed for variety of other uses such as cleaning cars, watering plants, ground water recharge etc., by preserving that water in a separate tank. To achieve this, segregation of water is required and that is where the 2-ways drain and actuator comes in: when the user presses the switch for the rinse mode, water pours out from the shower and drains into the clear water opening. The clear water drain is positioned 5mm higher than the "Grey water" drain which helps in segregating the two. When the user presses the mist mode or wash mode, the actuator opens the "Grey water" drain to release the contaminated water.

The system saves water in multiple ways. One, by providing mode segregation for shower wherein the user gets the option for the mist mode which drastically saves water and second, by segregating waste and "used water" allowing for re-purposing water for variety of different uses.

The system can be further enhanced by creating an end-to-end system of water usage in a bathroom: an integrated water-saving intelligent bathroom system which comprises a merged space including a shower area, a toilet area, a usable balcony area and a sewage area. The usable balcony contains a series of planters. The clean water used during the shower – first mode of rinse, flows from the bathroom directly to the planters placed in the balcony. As the water which is used to rinse the body before application of soap is fairly clean water without soap, the plants receive the clean water without the consumption of extra water specifically for that purpose. At the same

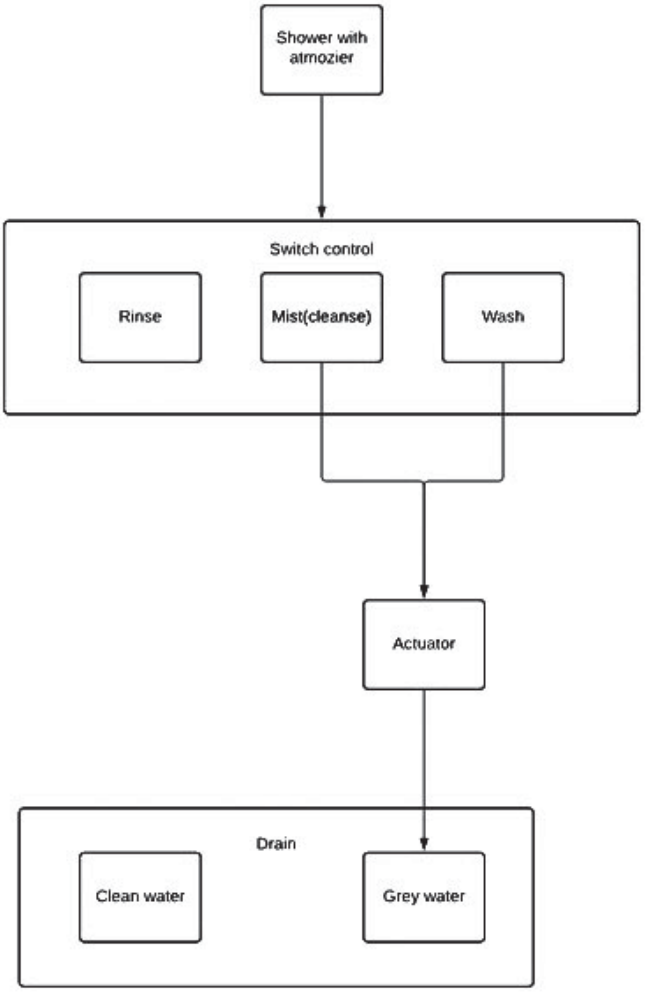


Figure 3: Illustrates the flowchart of the method according to the presented invention
Source: Author

time, the unclean water which is used to rinse off the soap from the body drains off to the sewer. The water from the mist mode also goes to the sewer but as the quantity of this water is negligible, not much water is wasted here. A diverter component is used to switch between the three modes of shower. Likewise, a drain actuator is used to divert the water to the drain or planters and allow the clean water to overflow to the planters.

In another embodiment of the invention, the water flowing to the plants can also be customised to flow to an underground water line.

The system further comprises a centralised plumbing system which relieves periphery walls from stereotype plumbing resulting in opening up walls for fresh air and green cover. The aim of this ecosystem is to ensure open circulation of fresh air in the toilet and reduced footprint.

Note: The figures are not intended to be exhaustive or to limit the present invention to the precise form disclosed. It should be understood that the invention

can be practiced with modification and alteration, and that the disclosed technology be limited only by the claims and equivalents thereof. The system disclosed herein, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The drawings are provided for purposes of illustration only and merely depict typical or example embodiments of the disclosed technology. These drawings are provided to facilitate the reader's understanding of the disclosed technology and shall not be considered limiting of the breadth, scope, or applicability thereof. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

With respect to the above description, it is to be realised that the optimum relationships for the parts of the invention in regard to size, shape, form, materials, function and manner of operation, assembly and use are deemed readily apparent and obvious to those skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Cited References

Online Citations:

https://www.hindustantimes.com/india-news/bengalurusurvey-points-to-water-shortage-in-nearfuture-experts-disagree-101647109865839.html#:~:text=debate%20once%20again.,According%20to%20the%20Economic%20Survey%2C%20the%20current%20shortfall%20in%20the,to%201%2C450%20MLD%20by%202031.

https://www.usnews.com/news/cities/slideshows/10-cities-most-at-risk-of-running-out-of- water?slide=8

Mueen Haris (A16167), a 2005 graduate in Bachelor of Architecture from the esteemed Vishveshwaraya College of Engineering (UVCE), firmly believes that effective space planning should maximise every inch, adhering to the philosophy that 'An inch saved is an inch used wisely.' He disregards the idea of a creative genius. Good architecture can only be achieved by a team of sensible individuals through design, dialogue & discourse. His practice in a nutshell, is based on the Japanese philosophy of "Kaizen", which translates to constant improvement, and entails that we question and dissect every design that we set out to build or create. As a tech-savvy individual with extensive industry knowledge, Mueen views DS2 not just as a business but as a close-knit family, and nurturing it accordingly.
Email: mueenharis@ds2.in

Architecture with a Soul! Sustainable, Optimal, Unique, Liveable

By Ar. Mrinalini Sane

An invigorating conversation with Ar. Rahul Kadam [RK], who strives to combine green principles into his architectural designs. He shares his experience and thoughts with Ar. Mrinalini Sane [MS].

From Pune to London and back home, armed with experience across various building typologies learnt from different firms, Ar. Rahul Kadam established The NGK Studio about a decade ago. NGK stands for Nature's Green Kinaesthetics. He has taught and mentored in several architectural schools in India. Also, he has presented papers on subjects related to Design and Planning in India and overseas on many coveted forums. He has travelled to many countries for project assignments and for studying architecture. His quest for excellence has helped him be part of award-winning published projects of repute in a professional career spanning over 25 years. The latest feather in his cap is the Jury Recommendation Award for Architectural Design in the AESA Awards 2025 for Bajaj Auto Ltd. Manufacturing Plant II, Chakan Phase III.

Ar. Mrinalini Sane [MS]: Please share a brief background about your education and initial work experience.

Ar. Rahul Kadam [RK]: I am an alumnus of BKPS College of Architecture, Pune, India. I completed my Masters from South Bank, London. I was a student member at AA, London, UK also. I travelled extensively before I started working with leading architects like Ar. Bimal Patel, Ar. Hasmukh Patel, Kamal Malik and Ar. Karan Grover. I have also been a Director and Regional Head at Edifice Consultants Pvt. Ltd. (ECPL), for 15 years, where I handled diverse portfolios like hospitals, hotels, Special Economic Zones, IT campuses, schools, neighbourhood urban design projects, adaptive reuse projects, workspace environments etc. in a cutting-edge corporate environment. Here at ECPL, I was fortunate to create workspace environments for diverse national and multinational corporations like TCS Ltd., Avaya Inc., Amdocs, MasterCard, Credit Suisse, CISCO, to name a few.

MS: How did the transition occur - to start on your own?

RK: Since the last 10 years I have my own design firm, 'The NGK Studio' in partnership with my wife Ar. Nandini RG Kadam. The 'NGK Studio', focuses on a sensitive design approach. We are a boutique firm with a team of about 8 to 10 people. However, we have worked with many diverse Indian and MNC clients. Some of our prestigious clients are Bajaj Auto Ltd., Elpro International Ltd., Kone, Microsoft, KSB, SAS Global R&D, DFPCL, Texas Instruments - to name a few. We have done master planning for campuses, manufacturing campuses, adaptive reuse projects, corporate work spaces, large and small cafeterias and landscape projects for these diverse clients.

As a committed architect, I believe that we must return to the society in whichever way we can. While I am a strong follower of the need for Sensitive Design and Green Design to pervade in all sectors of architecture and design, whatever the scale, I also believe in sharing about it. So, I try to walk the talk. I have taught and mentored in several architectural schools in India. I have presented papers on subjects related to design and planning, in India and overseas on many respected forums.

I like to travel and learn from my travels. Hence, I have used the project assignments as a reason to travel and study architecture in the process. I am of the strong opinion that my quest for excellence has helped me in many ways, not the least, to be a part of award winning and nominated projects in forums such as - A+D Awards, Architectural Review Awards, IIA Awards, JK Awards, International Property Awards, AESA Awards, etc. I am happy that projects designed by the NGK Studio are published in reputed journals and print media, in a professional career spanning over two and half decades.

MS: You mentioned about Awards. Please elaborate about a few Award-winning projects.

RK:

1. A+D Young Enthused Architect Award in 2001 (Commendation Trophy), for a courtyard Project at the Gujarat Law Society Campus in Ahmedabad.
2. FOAID – 20 Best Unbuilt projects in 2017 and 2018 in India for 'Utsah', a transformation management centre for Bajaj Auto Ltd in Akurdi, Pune and for Delicia, a Corporate Café for Bajaj Auto Ltd in Akurdi, Pune respectively.
3. Nominated for the 7 top institutional projects in India at IIA awards 2020.
4. 2nd place in a National Invited Competition for Microsoft for a Carbon Zero R&D campus in SEZ zone of Nodia, UP (we were 1 of 30 firms invited for this prestigious competition) in 2020.
5. AESA Beharay Rathi Awards 2024 (Non-Residential - Infrastructure and Industrial Projects), for the grand entrance canopy of the Bajaj Auto Chakan - 2 Plant, near Pune.
6. Contemporary Design Award 2024 for the Best Sustainable Work Space, by ITP Media house.
7. Net Zero Accelerator Award at the green conclave by ISHRAE 2025 for Bajaj Auto Ltd Chakan-2, Plant near Pune.

I am proud and happy that our designs and concepts have actually made a difference to the people who use the buildings and the surroundings. I feel, that the satisfaction that they feel is actually the best award!

MS: Please elaborate about your work ethics and concepts that you mentioned.

RK: We at the NGK Studio have always believed that our work must have legacy in times to come and in doing so we have always strived to practice our vision statement – 'Coming and going is not important; it is what you leave behind'. Further, at the studio there is a very conscious attempt made to design every project using the '3S'- principle of Sensitivity, Synergy and Sustainability in a holistic way – such that our projects positively contribute to society and

our beautiful planet (See Fig1)! Our work also tries to respect the local skill of our Indian crafts women and men - thereby attempting to create a – 'Glocal' language of architecture that fuses global values with local ones. We believe in the appropriate usage of 5 elements the *Panchamahabhuta*, in our design of built environments. Wherever possible, we try to use knowledge of our ancient architecture in the current forms. This helps us to design in the green way.

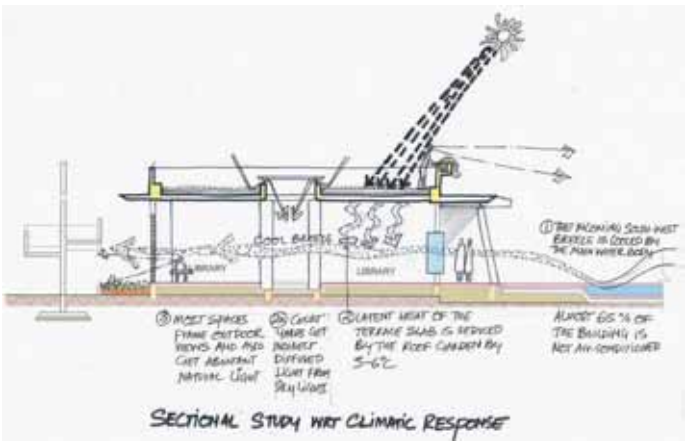


Figure 1: Sectional study of understanding climatic response.

MS: Please share some specific examples from your recent projects that help us understand your journey from design sketch to completed structures.

RK: I will take the Bajaj Projects to explain our working.

1. Project – 'Utsah '-A transformation management centre for Bajaj auto Ltd on a 6.5 acres of land and 44,000 sqft BUA, at their Akurdi, Pune campus - this project strives for a mind body soul connection at the work space (see Fig 2, 3).
2. Bajaj Auto Ltd – Chakan - 2 Plant – This is an exports plant of Bajaj Auto Ltd., spread over 188 acres and Phase -1 BUA is almost a million sqft. The Idea has been to design a humane campus for people to work in (see Fig 4, 5).
3. Bajaj Auto Ltd – Chakan -2 Plant office - This work space has been designed on the concept of a garden office and tries to create a very sustainable design space that motivates end users with its Biophilic effect. It is almost 15,000 sqft in BUA (see Fig 6, 7).

MS: Your sketches indeed translate into reality with a great fidelity!

RK: Yes, we pay a lot of attention to design fidelity to actually see that the ideas are executed into the built structure the way we envisioned! That way, the client is also happy to see that the sketch that was

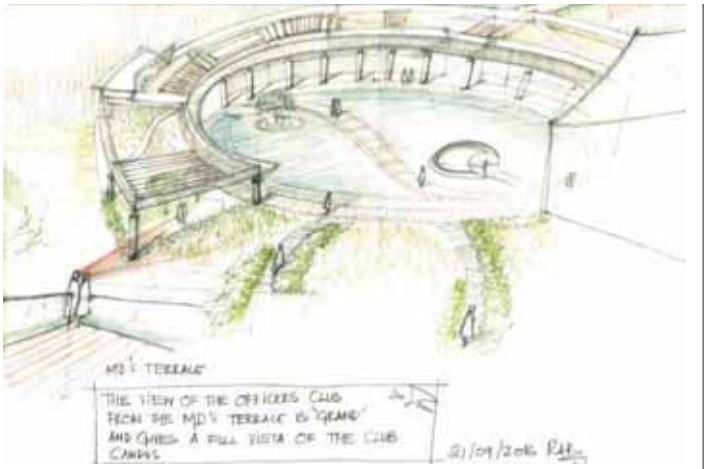


Figure 2: Sketch of Yin-Yang water body as a Focal point/Epicentre

Figure 3: Here we have envisioned the master plan as a painting in the frame of landscape!

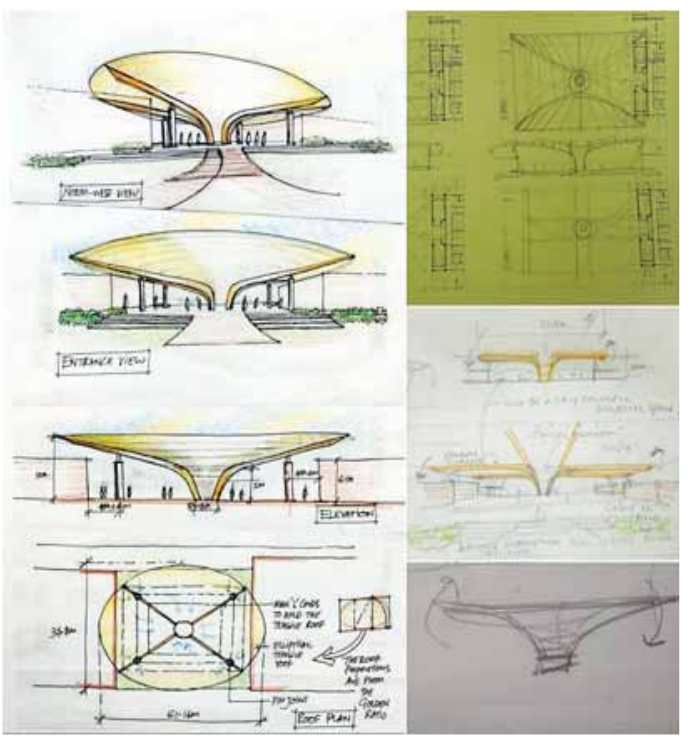


Figure 4: Sketch evolution - Designed using a balance Cantilever principle for a Grand Entrance Canopy

impressive on paper, is now, a vista, a built space that really amazes and is realised.

Figure 5: Grand Entrance Canopy

Figure 6: Articulation using 5 elements of nature and is like a living organism!

Figure 7: View of the workspace with the 5 elements integrated

MS: Please explain about the usage of *Panchmahabhuta* and Net Zero building design.

RK: We have tried to go towards net zero goals by respecting the five elements of nature, in our work as follows:

i. **Fire Elements** – It is associated with solar energy and its use to save electricity by making provision for photovoltaic harvesting areas on the Southern and Western roof tops/slopes considering the sun path of the context we work in. Fire which is represented by sun light, is effectively used as filtered diffused light in the various spaces (Fig 8).

Figure 8: Brick jali for filtered sunlight

ii. **Water Element** – It is associated with harvesting rainwater to make campuses/projects self-sufficient and water surplus, by rejuvenating perineal existing water bodies at site. Also, a conscious attempt to harvest almost 75% of roof terrace water and pavement storm water is made; and of course, the STP water is recycled for landscape irrigation.

iii. **Earth Element** – It is associated with understanding the site topography, by locating the largest footprints of the buildings on the flattest part of the site and further - reusing the basalt stone from the site excavation for plinth and retaining wall work to optimise construction cost. This element is achieved by using red wire cut bricks with low embodied energy made from reused clay and Murum in plinth work and retaining walls recovered from the site excavation (Fig 9). Also, the landscape planned is considering local plant species to maintain the fertility of the soil.

iv. **Air Element** – It is associated with cross ventilation and aiming towards a 'Zero' air conditioning goal by careful planning of cross ventilation and 'Stack Effect' for most of the

Figure 9: Usage of Murum in plinth

buildings, combined with high velocity fans and evaporative cooling to reduce operational electricity cost by 6 to 7 times (almost 78% electrical load). Also, by compressing hot winds by brick *jali* with interior spaces that are insulated by rat trap bond, we have been able to achieve a reduction of 8 degrees in interior cooling by this method (see Fig 7,8,9).

v. Space Element – It is associated with a motivational work environment that touches the human senses of end users in a positive way such that they are more productive and happier about their workspace due to its spatial quality. Here landscape plays a pivotal role by bringing the O_2 effect into the space, through regional plants and freshness. We have tried to create a series of delicate, sensitive and vibrant spatial experiences that have a visually motivating spatial effect (see Fig 10)!

All these projects are strategic design interventions done with a view of designing green buildings/ campuses. This strategy has helped save a lot of Capital Expenses - Capex cost. In addition, we and the client, are happy to note that the Operational Expenses - Opex are also reduced. Energy savings to the tune of up to 40% have been observed! Furthermore, these strategic design interventions have had a positive effect on retaining the best talent for our clients. Prior to these strategic interventions, attrition rate was around a double digit %. In 3 to 5 years, after realisation of these projects and their use, attrition rate dropped to a single digit %. This, I believe, is due to the role played by good architecture on the mental and emotional well-being of the end users of the spaces. Hence, I can say with great confidence, that architecture with a holistic approach, certainly has worked for the client's benefit in direct as well as incalculable, intangible, indirect ways.

MS: How do perceive the role of your client in your success?

RK: Our clients have played a pivotal role in creating the projects we want! We are on the same page, on the same side of the table, with common goals.

Figure 10: The Greens inside create an element of freshness!

From their encouraging and dedicated support for a common vision of holistic, sensitive and sustainable design, to working with us as responsible team members without barriers, trying to address the same concerns that we all want to, with respect to the responsive architecture, for the greater good of our society and planet!

All Images Courtesy: Ar. Rahul Kadam

Ar. Mrinalini Sane (A-10915) is a practising architect and interior designer with 35 years of experience. Since 1993, she has served as visiting faculty at several architecture colleges. She is the Editor of Smaranika – IIA Maharashtra Chapter Souvenir and has been an Executive Committee member of PCERF for over 20 years, also convening the PCERF Vidyarthi Awards. A member of the JIIA Editorial Board, she contributes uniquely to the profession as an ISO Auditor, Consultant and Trainer, promoting Quality Management Systems for efficiency in construction practices. She has represented India via the Rotary GSE programme and co-authored a Civil Engineering book.
Email: mmsane@gmail.com

ADVERTISE WITH JIIA

SR. NO	TYPE	1 ISSUE	3 ISSUES	6 ISSUES	12 ISSUES
1.	BACK COVER	NIL	9,00,000	15,00,000	24,00,000
2.	FRONT AND BACK				
A	INSIDE COVER (1 PAGE)	NIL	6,00,000	10,00,000	18,00,000
B	INSIDE COVER (2 PAGES, FULL SPREAD)	NIL	9,00,000	15,00,000	24,00,000
3.	FULL SPREAD INSIDE (2 PAGES)	2,00,000	6,00,000	10,00,000	18,00,000
4.	FULL PAGE	1,00,000	3,00,000	5,00,000	9,00,000
5.	HALF PAGE	50,000	1,00,000	1,50,000	2,50,000

JIIA ONE YEAR SUBSCRIPTION

GENERAL

MEGASAVER
GENERAL SUBSCRIPTION
Other than IIA members

JOURNAL OF
THE INDIAN INSTITUTE OF ARCHITECTS

Prospect Chambers Annexe, 5th Flr., D.N. Road, Mumbai 400 001
Tel.: +91 22 22046972/22818491/22884805 Fax: +91 22 2283 2516
Email: iiapublication@gmail.com

Please enter my annual subscription at Rs. 1500/-
Payment is enclosed herewith. (Please tick appropriately)

☐ Demand Draft ☐ Cheque ☐ Money Order

Name: Title

Address:

City: Pin:

Signature: Date:

Please tick the appropriate box only

- ☐ Architect registered with the Council of Arch Arch. CA No.
- ☐ Planner
- ☐ Engineer
- ☐ Builder
- ☐ Designer
- ☐ Educationist
- ☐ Administrator
- ☐ Business
- ☐ Other than above (Please Specify)

STUDENT

MEGASAVER
GENERAL SUBSCRIPTION
Other than IIA members

JOURNAL OF
THE INDIAN INSTITUTE OF ARCHITECTS

Prospect Chambers Annexe, 5th Flr., D.N. Road, Mumbai 400 001
Tel.: +91 22 22046972/22818491/22884805 Fax: +91 22 2283 2516
Email: iiapublication@gmail.com

Please enter my annual subscription at Rs. 1000/-
Payment is enclosed herewith. (Please tick appropriately)

☐ Demand Draft ☐ Cheque ☐ Money Order

Name: Title

Address:

City: Pin:

Signature: Date:

CERTIFICATE

This is to certify that

(Student's Name)

is a bonafide student of

(School, College of Arch)

City

Please enter student Subscription

Signature of Head of the Institution
(Please affix stamp of the Institution

IIA CAD

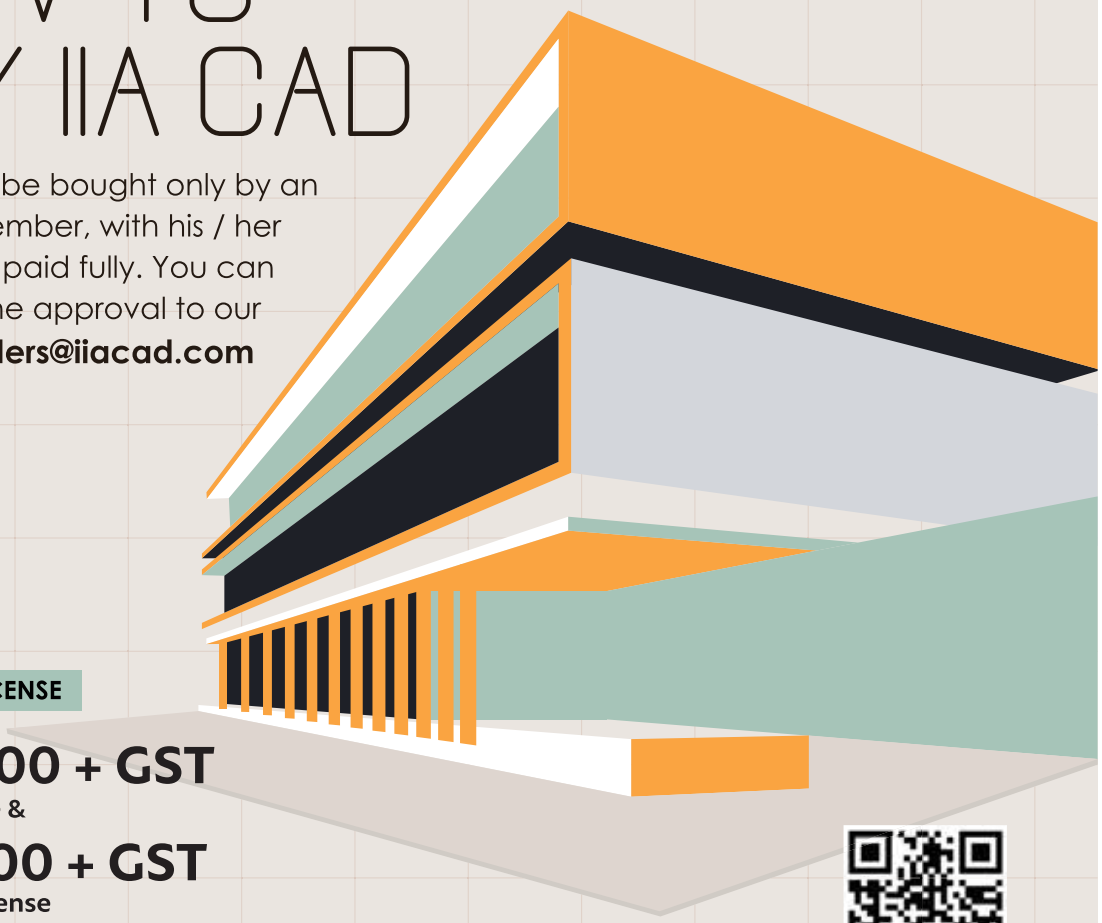
The #1 Alternative CAD for IIA Members

ONE MEMBER IIA CAD

An initiative of Indian Institute of Architects

HOW TO BUY IIA CAD

IIA CAD can be bought only by an active IIA member, with his / her membership paid fully. You can request for the approval to our email id : **orders@iiacad.com**



PERPETUAL LICENSE

Rs.26,000 + GST
for stand alone &

Rs.32,500 + GST
for network license

IIACAD Supports

www.iiacad.com

NATIVE DWG SUPPORT

IIACAD is a powerful, innovative DWG based CAD Software developed by IIA for it's members

WORK OFFLINE

Fully installed on your computers as you have ever been used to

COST EFFECTIVE

IIACAD is an affordable, cost effective and perpetual CAD solution

EASY SWITCH

IIACAD has similar, friendly User Interface, Commands and Shortcuts

IIACAD Supports PreDCR based E filing of Govt of Kerala, Maharashtra (TP Client) and Uttar Pradesh

90/6
IIA PUBLICATION
POSTAL REGD. NO.MCS/007/2024-2026

RNI NO.9469/57
POSTED AT PATRIKA CHANNEL SORTING OFFICE, MUMBAI-400001
PUBLISHED ON 14TH OF EVERY FOLLOWING MONTH AND
POSTED ON 15TH & 16TH OF EVERY FOLLOWING MONTH

Award instituted by JK Cement LTD., Kanpur, India, From 1990