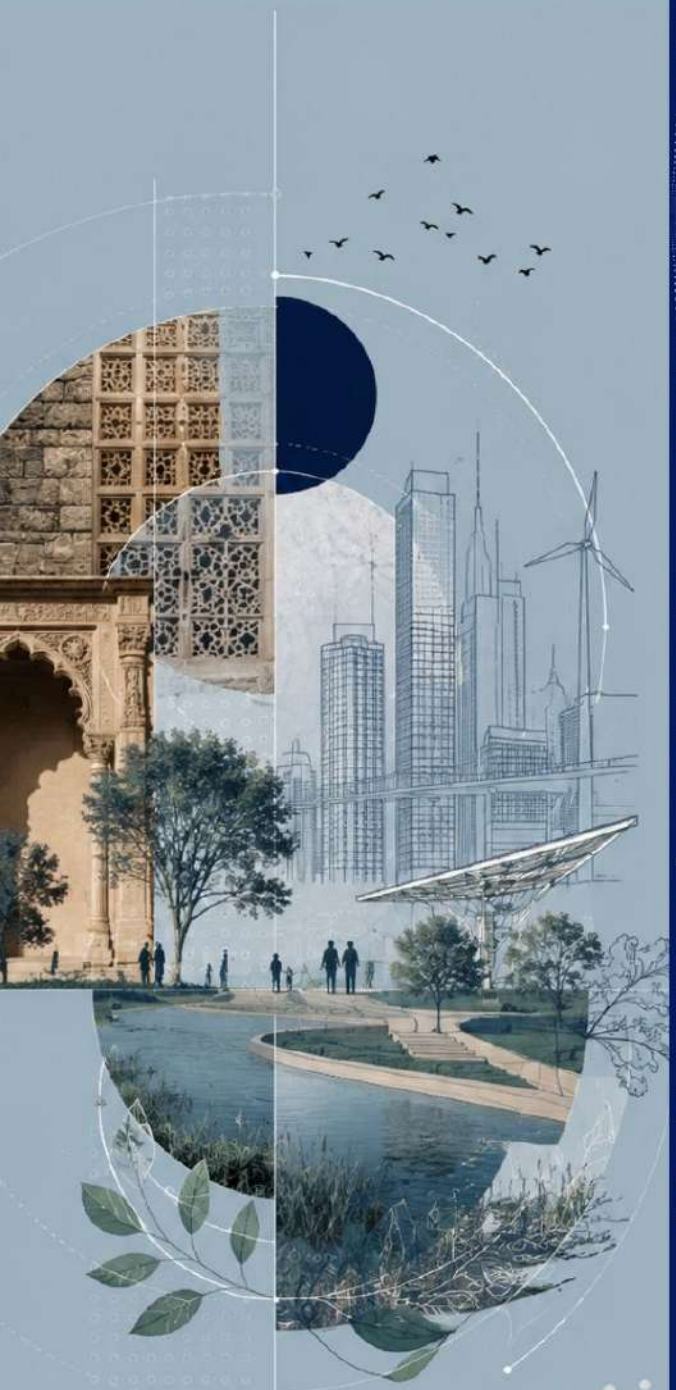


2026 - Conference Proceedings

NATIONAL CONFERENCE ON

Built Environment and Beyond 4.0

FROM TRADITIONAL WISDOM TO RESILIENT FUTURE

Peer Reviewed - (eBook ISBN: 978-81-955887-3-2)

MKSSS's Dr. B.N College of Architecture for Women, Pune
Affiliated to Savitribai Phule Pune University

BNCA
MAHARSHI KARVE STREE SHIKSHAN SAMSTHA'S
DR. BHANUBEN NANAVATI
COLLEGE OF ARCHITECTURE
FOR WOMEN
KARVE NAGAR PUNE 411052

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BNCA Research Hub (BRH)

Built Environment and Beyond 4.0:

from Traditional Wisdom

to Resilient Future

3rd and 4th February 2026

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Editors

Dr. Sanjeevani Pendse and Dr. Prajakta Kulkarni

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This Publication is based on the "National conference on Built Environment and Beyond 4.0: From Traditional Wisdom to Resilient Future" held on 3rd February and 4th of February 2026 at Dr. Bhanuben Nanavati college of Architecture for Women, Pune. The Event was organized by BNCA Research Hub (BRH).
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Founder member and Former Principal's Note

BNCA (Dr. Bhanuben Nanavati College of Architecture for Women), MKSSS (Maharshi Karve Stree Shikshan Samstha) runs one of the most significant Ph.D. centers in India, affiliated to the state university: SPPU (Savitribai Phule Pune University). To enhance the research component further, in the context of the NEP 2020 (National Education Policy, India), BRH (BNCA Research Hub) was established at BNCA in the year 2021 to create an interdisciplinary and collaborative platform. This platform envisioned to facilitate and encourage research interactions, innovations and interconnections amongst aspiring and established researchers from institutions, practice and industry.

National Conference was one such activity initiated by BRH. The aim of starting the annual conference is to cultivate and nurture the culture of research in the field of architecture and allied disciplines and to encourage students, academicians, and practitioners to write and present their research. The collaborative research platform organized its first Conference titled "Built Environment and Beyond: Theory and Practice" in the year 2022, followed by the second in line titled "Built Environment and Beyond 2.0: Theory, Practice and Pedagogy". The third National Conference in line titled 'Built Environment and Beyond 3:0: Challenges and Opportunities' (in Hybrid Mode). The fourth National Conference was seen as the successor to the earlier to continue tiltled ***'Built Environment and Beyond 4.0: From Traditional Wisdom to Resilient Future.*** BRH conference with its commitment to facilitating research has set up a systematic and rigorous process of peer-review and at the same time encouraging research through mentoring by domain experts invited at BRH, BNCA. This conference brought together knowledge partners such as the esteemed Council of Architecture (COA), India, Architects, Engineers and Surveyors Association (AESA), Pune, Indian Institute of Architects (IIA), Pune Chapter, Indian Green Building Council (IGBC) and Indian National Trust for Art and Cultural heritage (INTACH), Pune Chapter to initiate discussions on ***Built Environment and Beyond 4.0: From Traditional Wisdom to Resilient Future.***

Keynote speaker for the first day was **Dr. Tejas Garge** at present Director, Directorate of Archaeology and Museums, Maharashtra state, INDIA leading several projects of conservation of monuments, excavation- explorations, exhibition and museum development and also served Archaeological Survey of India for 13 years in Delhi, Haryana, Gujarat and NE India. Keynote speaker for the second day was **Dr.Rohit Jigyasu** a conservation architect and risk management professional from India, currently working at ICCROM as Programme Manager on sustainable urban and built Heritage conservation, disaster and climate risk management & post crisis recovery.

This volume of Conference Proceedings comprises blind peer-reviewed papers evaluated by a diverse panel of reviewers from across India, each possessing deep expertise in their respective areas. The themes represented reflect a holistic view of the built environment and the evolving discourse within the field of architecture. This compilation is the result of the unwavering commitment and collaborative efforts of the Convener, Co-Convener, and the Advisory Committee, whose contributions have been instrumental in making these endeavors a resounding success.

I am thankful to all mentors, reviewers and experts for their valuable inputs and guidance that made this scientific and academic endeavors a success.



Dr Anurag Kashyap
Founder member and Former Principal, BNCA

Founding member and Principal In-charge's Note

It gives me immense pleasure to present the proceedings of the BNCA Research Conference, an initiative that has steadily evolved into a vibrant platform for academic dialogue, critical inquiry, and dissemination of architectural research. As I take up the responsibility of Principal In-charge of Dr. Bhanuben Nanavati College of Architecture, I am honored to contribute to this continuing tradition of scholarship that our Institution has nurtured over the years.

At BNCA, research is viewed as a means of understanding and addressing complex challenges of the built and unbuilt environment. Our sustained engagement, especially through the Fourth Year Research in Architecture course for which I contribute as Subject Co-ordinator, Interdisciplinary Electives, participation in the SPPU Avishkar Research Competition, and the Annual BNCA Research Conference reflects our commitment to cultivating a strong research culture among students and faculty alike. In Avishkaar 2024 BNCA Student was the only student of Architecture who represented SPPU where SPPU was Runner-up at State Level. The consistent recognition received by our students at the University level is a testimony to this collective effort.

The papers presented in this volume demonstrate thoughtful exploration across diverse themes, thereby reinforcing the role of research in advancing Architectural Profession and shaping responsible professionals.

I congratulate all the Authors, Reviewers, Faculty mentors, Organizing Committee, and collaborators whose dedication has made this publication possible. I hope these proceedings will inspire further research, encourage meaningful collaborations, and contribute to the advancement of architectural knowledge and practice.

I extend my best wishes for the continued growth of the BNCA Research Conference and I look forward to seeing it emerge as a Nationally Recognized platform for innovative and impactful research.

Research with Purpose. Lead with Vision. Build for Humanity.

Contribute to Nation Building!!



Dr. Shubhada Kamalapurkar
Founding member and Principal In-charge, BNCA

A note from BRH (BNCA Research Hub)

The first national conference of BNCA Research Hub (BRH) was held on October 18-19, 2022, on a virtual platform. The theme of the conference was *'Built Environment and Beyond: Theory and Practice'.*
The second national conference of BNCA Research Hub (BRH) was held on November 2-3, 2023, on a virtual platform. The theme of the conference **was** *'Built Environment and Beyond 2.0: Theory, Practice and Pedagogy'.* Last year, the theme involved pedagogy as one of its significant sub-themes and deliberated upon the same in the conference.
We, at BRH, BNCA are happy to come up with the proceedings of each of these conferences including the third national conference held on 28th February and 1st March, 2025, on *'Built Environment and Beyond 3:0: Challenges and Opportunities'* (in Hybrid Mode).
This year being the fourth consecutive year of organizing this conference, which was held on ***3rd February and 4th February, 2026, on 'Built Environment and Beyond 4:0: From Traditional Knowledge to Resilient Future' (in Online Mode)***, the theme intended to address the rootedness in traditional knowledge, at the same time gave an opportunity to put forward research which investigates into future. We were immensely grateful to Council of Architecture (COA), India, Architects, Engineers and Surveyors Association (AESA), Pune, Indian Institute of Architects (IIA), Pune Chapter, Indian Green Building Council (IGBC) and Indian National Trust for Art and Cultural heritage (INTACH), Pune Chapter for joining hands with BNCA''s BRH. This was a great opportunity for students, academicians, professionals and researchers to share their research, knowledge and innovation perspectives from their own domain and expertise. The interdisciplinary dialogues and exchanges that happened during the sub-theme-based panel discussions with panelists across the nation were full of learnings and idea-exchanges, giving direction to future research for young researchers.

Like every year, to practice the rigor of the research activity, a call for abstract, a call for paper and a blind peer review process was followed for selection and finalizing of the content of the final papers. The manuscripts were received and reviewed by the expert reviewers based on the sub-themes of the conference. Comments and suggestions by panelists of the theme sessions during the conference were incorporated in the final papers. The whole process was carried out systematically pre and post conference with plagiarism checking, peer reviewing and finally publishing the papers in the book in the form of proceedings of the conference. This year's conference too like last three years was very well received and was participated by students, faculty, and professionals across India.

We, at **BRH-BNCA**, look forward to many such meaningful conversations and learning opportunities for researchers and scholars in the field of architecture and alike. Wishing all the best and
Happy researching!



Dr. Swati Sahasrabudhe,
Ph.D. Professor, Head, BRH (BNCA Research Hub)

Editor's Note

The built environment today stands at a defining moment. Rapid urbanization, climate change, resource depletion, and increasing social inequalities have brought unprecedented challenges that call for resilient, innovative, and sustainable solutions. At the same time, there is a growing realization that many of these solutions lie in the integration of traditional wisdom with modern technologies. Indigenous knowledge systems, vernacular practices, and community-led approaches, complemented by advancements in digital technologies and sustainable innovations, offer valuable opportunities to shape a resilient future.

The fourth edition of the ***National Conference, Built Environment and Beyond 4.0: From Traditional Wisdom to Resilient Future*** was envisioned as a platform to explore these evolving dimensions of the built environment through interdisciplinary research and dialogue. The conference brought together academicians, researchers, professionals, policymakers, and students to exchange ideas and explore approaches that strengthen the relationship between tradition, technology, sustainability, and resilience.

The conference invited papers under six broad themes: ***Traditional Knowledge Systems and Local Practices; New Technologies for Resilience; Resilient Urban and Ruralscapes; Equity, Inclusion and Social Well-being; Infrastructure and Mobility Systems; and Sustainability and Low-Carbon Built Environment.*** These themes encouraged research on climate resilience, vernacular architecture, digital planning tools, sustainable mobility, community participation, inclusive planning, and low-carbon development.

The conference received an overwhelming response from researchers, academicians, professionals, and students from across the country. The technical sessions provided valuable discussions on the opportunities and challenges of integrating traditional knowledge with emerging technologies to address contemporary issues in the built environment.

Every paper underwent a rigorous double-blind peer review and plagiarism check process. Only those that met the prescribed academic standards, including a plagiarism limit of 10%, were accepted for presentation and publication in the Conference Proceedings. Selected papers were revised by the authors incorporating the suggestions and feedback received from reviewers and session experts before publication in this peer-reviewed volume. A few of the best papers were further recommended for publication in a Scopus-indexed journal.

We are delighted to present this compilation of research and sincerely thank all the authors, reviewers, session chairs, keynote speakers, and organizing committee members for their valuable contributions. We hope these proceedings will encourage further research, foster interdisciplinary collaborations, and continue the dialogue towards creating resilient, inclusive, and sustainable built environments.



Dr Sanjeevni Pendse
Convener



Dr Prajakta Dalal - Kulkarni
Co-convener



Ar. Sayali Kulkarni
Co-ordinator

Acknowledgements

We take this opportunity to express our heartfelt gratitude to everyone who contributed to the successful organization and publication of *the **Fourth National Conference on "Built Environment and Beyond"**, hosted by **BNCA Research Hub (BRH), BNCA***. We extend our sincere thanks to ***Dr. Anurag Kashyap, Former Principal, BNCA***, for his visionary leadership, constant encouragement, and unwavering support in strengthening the research culture at the institution. We are thankful to ***Dr. Shubhada Kamlapurkar, Principal In-Charge, BNCA*** for her encouragement and support. We are equally grateful to ***Dr. Sharvey Dhongde, Vice Principal***, for his continued guidance and administrative support throughout the process; A special note of appreciation to ***Dr. Swati Sahasrabudhe, Head, BNCA Research Hub***, for her support. We sincerely thank the knowledge partners for this conference Council of Architecture (COA), India, Architects, Engineers and Surveyors Association (AESA), Pune, Indian Institute of Architects (IIA), Pune Chapter, Indian Green Building Council (IGBC) and Indian National Trust for Art and Cultural heritage(INTACH),Pune Chapter.

We would like to express our deep appreciation to the ***Advisory Board Members*** for their valuable insights, mentorship, and encouragement that shaped the direction of the conference. Our heartfelt thanks to the ***esteemed Keynote Speakers, Dr. Tejas Garge*** *at* present Director, Directorate of Archaeology and Museums, Maharashtra state and ***Dr. Rohit Jigyasu*** a conservation architect and risk management professional from India, currently working at ICCROM as Programme Manager for their thought-provoking addresses that enriched and inspired all the conference participants. We acknowledge with gratitude the commitment of the ***Review Committee Members***, whose meticulous peer review process ensured the academic quality and relevance of the papers published in these proceedings. We thank the ***Coordinators*** and ***Panel Chairs***, for their effective management and facilitation of the conference sessions.

A big thank you to the ***IT Department*** for providing the necessary technical support, ensuring seamless communication and digital infrastructure during the conference. We also sincerely acknowledge the enthusiastic contributions of our ***volunteers***, especially the ***student volunteers***, who worked tirelessly behind the scenes to make this event a smooth and successful one.

Lastly, we thank all previous BNCA Conference Convener and Co-Convener for their constant support and guidance throughout whole process. We thank all the authors, presenters, attendees, and well-wishers who were part of this academic endeavour. Your active participation and scholarly contributions have added immense value to this platform for collaborative research and knowledge exchange.

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Keynote Address – *3rd February 2026*



Dr. Rohit Jigyasu

Rohit Jigyasu is a conservation architect and risk management professional from India, currently working at ICCROM as Programme Manager on sustainable urban and built Heritage conservation, disaster and climate risk management & post crisis recovery.

Rohit served as UNESCO Chair holder professor at the Institute for Disaster Mitigation of Urban Cultural Heritage at Ritsumeikan University, Kyoto, Japan, where he was instrumental in developing and teaching International Training Course on Disaster Risk Management of Cultural Heritage.

He was the elected President of ICOMOS-India from 2014-2018 and president of ICOMOS International Scientific Committee on Risk Preparedness (ICORP) from 2010-2019. Rohit served as the Elected Member of the Executive Committee of ICOMOS since 2011 and was its Vice President from 2017-2020.

Before joining ICCROM, Rohit has been working with several national and international organizations such as UNESCO, UNDRR, Getty Conservation Institute and World Bank for consultancy, research and training on Disaster Risk Management of Cultural Heritage. He has undertaken post disaster assessments in India, Nepal, Bhutan and Japan. He worked on the updated policy document on climate action for world heritage adopted by UNESCO General Assembly in 2023 and is also the main author of the UNESCO Resource Manual on Managing Disaster Risks for World Heritage and the co-editor of recently published Routledge handbook on cultural heritage and disaster risk management and Routledge book on Good Practices for Disaster Risk Management of Cultural Heritage.

Keynote Address – *4th February 2026*



Dr. Tejas Garge

Dr. Tejas Garge is at present Director, Directorate of Archaeology and Museums, Maharashtra state, INDIA leading several projects of conservation of monuments, excavation-explorations, exhibition and museum development. He served Archaeological Survey of India for 13 years in Delhi, Haryana, Gujarat and NE India.

He was instrumental behind getting 12 Maratha forts inscribed as the World Heritage site, extradition of Senasubha Raghuji Bhonsle Sword and organization of international exhibition on Maratha Arms including Tiger Claws of Chhatrapati Shivaji Maharaj. He directed excavations at Koloshi in Sindhudurg district and has been instrumental in process of World Heritage Nomination of Geoglyphs in Konkan, and Sea Forts of Maharashtra.

He obtained his PhD from Deccan College, Pune and at present he is considered as an expert on the Harappan Studies, medieval fire arms, Indian art- architecture and heritage policies. He participated in excavations including Dholavira, Rakhigarhi, Shravasti, Balathal etc. and participated in numerous projects of archaeological research. He was deputed to Republic of China and USA as representative of Government of India. He has authored 4 books and co-authored 11 monographs on inventories of monuments, study of firearms, archaeology and art history. He is credited for publication of 52 papers in international and national journals. He is also visiting faculty and expert for syllabus designing for several Archaeology Departments in many Universities across India. He is on Board of Trusties for CSMVS Museum, Mumbai, MMR-Heritage Society, and Maritime Heritage Society.

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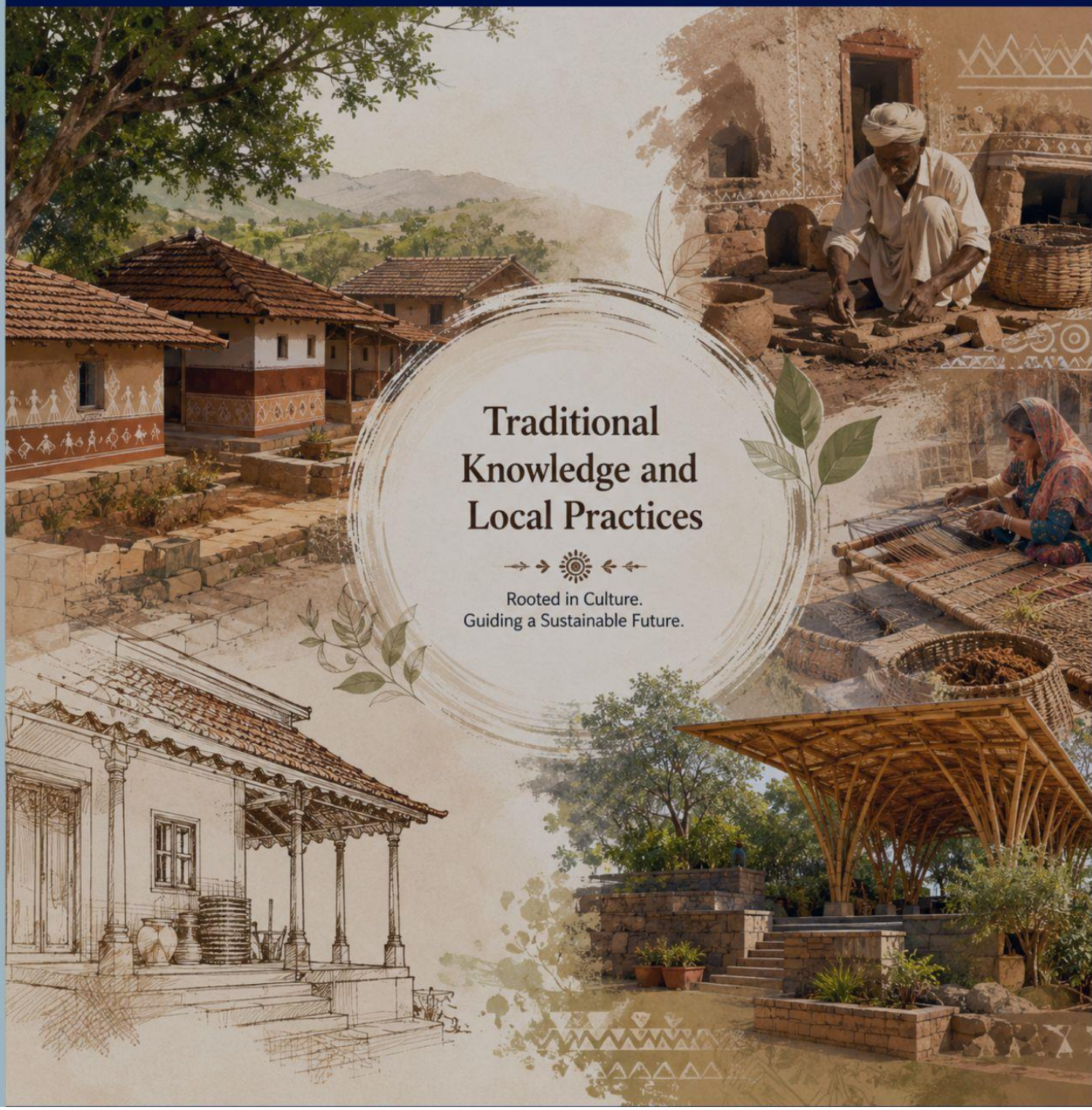
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TRACK 01

TRADITIONAL KNOWLEDGE AND LOCAL PRACTICES



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Traditional Wisdom in Contemporary Design: Rajasthan's Architectural Synergy in Response to Climate Resilient Design.

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Abstract: India has a profound and diverse architectural heritage. Over the years, various parts and regions of the country have reflected variety of patterns and styles of design. These styles are not only in aesthetical sense but also carefully thought considering the regional, environmental needs and fundamental requirements of the users considering their comfort conditions. There is a perceptible variation in the buildings the way they appear aesthetically but parallelly there is a strong flavour of traditional wisdom in the modern construction. This traditional knowledge serves as the basic of climate resilient design which refers to planning, designing, and constructing buildings, landscapes, and urban systems that can withstand, adapt to, and recover from the impacts of climate change while minimizing environmental harm ensuring long-term sustainability.

In light of this context, the research tries to decode some of the traditional construction techniques and elements which are carefully transferred in the modern architecture to achieve the desired result. As a part of analysis, the research considers some of the case studies in Rajasthan to understand an influence of traditional design elements used in modern structures. Having a rich legacy of traditional architecture, Rajasthan demands for design considering challenging climatic conditions along with sustainable design and logical selection of materials.

The aim of the research is to identify, analyse and study the traditional knowledge used for contemporary design in Rajasthan. The objective of the research is to decode how the traditional knowledge is used to fulfil the climate resilient design, aesthetic and user-centric demands in the modern and local architecture.

Keywords: Traditional knowledge; Modern architecture; Construction style; Sustainable design; Climate responsive architecture

1. Introduction

Being one of the oldest civilization, India reflects high impact of various aspects on its style of architecture. Some of the major considerations are weather conditions, cultural roots, customs, lifestyle, geographical conditions, rule of various dynasties and so on. One of the strongest of all considerations is weather conditions. India being strategically

placed in the globe experiences all the seasons during the year. Having said that some of the regions of the country faces harsh climatic conditions and need a specific plan of action to mitigate with the extreme climatic settings. Whoever ruled India over the period of time has set their own style of architecture according to their requirements but common string between all was climate.

Climate zones of India are crucial as far as space designing is concerned. Various climate zones demand for number of design elements to be incorporated in the buildings. On a broader picture, there are seven climate zones in India. **Figure 1** indicates the zones that exist in India. Climate responsive and climate resilient design are always prioritized in order to meet the user-friendly comfort conditions. The research focuses on a hot and dry climate of Rajasthan to analyse the design response and adapted strategies. The region experiences extreme climatic conditions because of which design approach is always found to be challenging. (Ahuja, 2024) Historically, it is observed that specific methodologies are adapted in order to sustain in the extreme climatic conditions. Various modes of construction and material usage is experimented over few decades to conclude and enlist design elements and material selection which ensures positive response to the harsh climate.

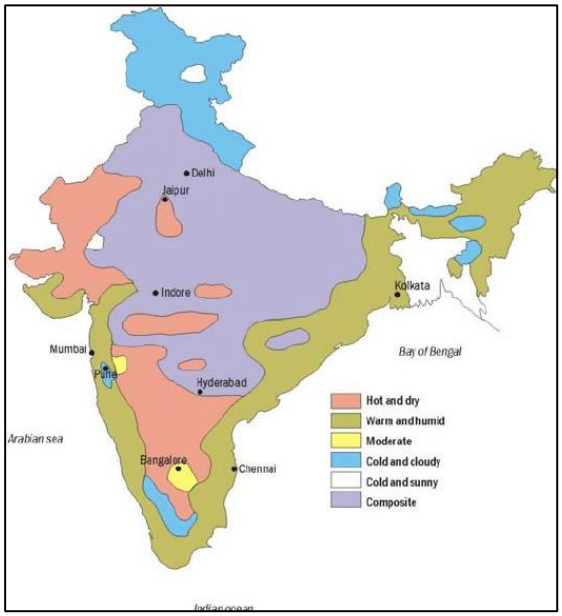


Figure 1. *Showing climate zones of India*
Source: *Climate zones of India | Download Scientific Diagram*

Various regions in India experience harsh weather conditions depending upon their geographical location. This brings in lot of challenges and obstacles as far as the space planning and architectural style is concerned. Local population is always seen adapting the weather conditions but at the same time many of such regions expect either migrated population or tourists who find it extremely difficult to get acclimatized with the conditions. Indian designers have adapted core design strategies since ages to mitigate the harsh weather challenges.

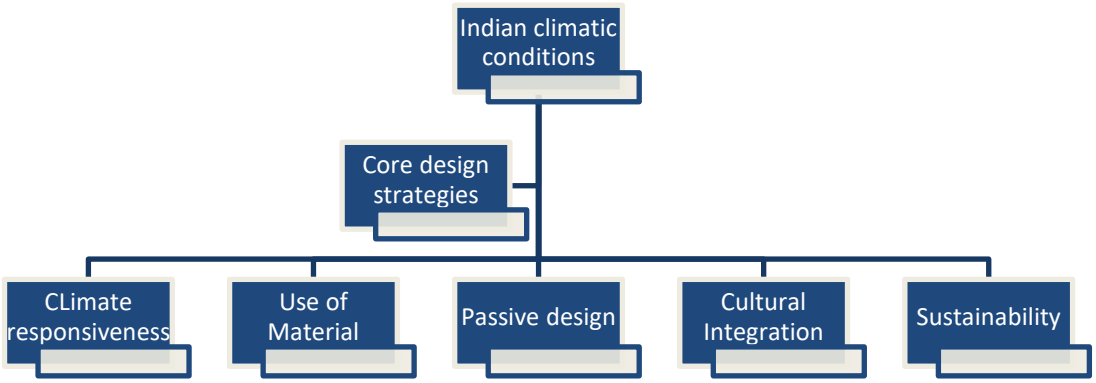


Figure 2. *Showing Indian core design strategies (Source: Author)*

Figure 2 reflects various traditional techniques which guide designers to achieve user comfort in the extreme conditions. Influence of these design strategies is seen in the work of great architects who have completed their work in these conditions. The work done in these conditions show high integration towards climate responsive approach instead of climate repellent approach. All the core design strategies have always considered climate as a part of design rather than keeping it out of the building.

2. Background

The research considers an example of Jaipur situated in the state of Rajasthan which according to **Figure 1** falls under Hot and Dry climate. Having a rich architectural history, Jaipur has many well-known structures which reflect an impulse of climate responsive architecture. The city unfolds an interesting approach to resolve the weather challenges with a rich architectural flavour to it. Traditionally built structures in the city exhibit an architectural ideology which ensures that extreme weather conditions is not an obstacle to achieve well designed and user-friendly structures.

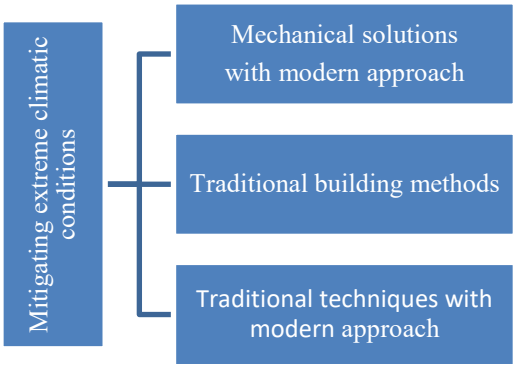


Figure 3. *Showing possible architectural solutions*
Source - Author

Technically, mitigating extreme climatic conditions open up few options as shown in **Figure 3.** In the modern era, designers can map out an option which explores mechanical solutions to fight with challenging climatic conditions by introducing technological methodologies including HVAC systems. Other option is to remain stuck with the traditional building and space planning. The third option which this research tries to open up with is to adapt traditional techniques with modern approach. Architectural case studies are considered from Jaipur city to analyse the effectiveness of such strategies. The research tries to identify how traditional design elements and space planning techniques enhance the user experience and achieve user centric comfort conditions in contemporary buildings. As a part of methodology, the research tries to gain some insights from professionals to understand how such adaption is relevant in the contemporary style without compromising the look and feel of the modern

buildings. It also gives an opportunity to figure out what are the shortfalls that are stopping or resisting architects to adapt such techniques as a part of regular practice in the current era.

2.1 Aim

The aim of the research is to identify, analyse and study the traditional knowledge used for contemporary design in Jaipur, Rajasthan.

2.2 Objectives

a. To study traditional techniques and architectural elements used in buildings constructed in Jaipur as a part of climate responsive design.
b. To analyse how contemporary buildings are designed for extreme climate by studying cases of couple of well-known buildings designed in Jaipur.
c. To compare how traditional elements and design strategies are adapted in contemporary buildings to achieve climate responsive design.
d. To decode how the traditional knowledge is used to fulfil the climate resilient design, aesthetic and user-centric demands in the modern and local architecture.

2.3 Research Question:

How effective the traditional design knowledge is to achieve climate responsive architecture in contemporary buildings?

2.4 Scope and Limitations

2.4.1 Scope:

a. To study and understand various techniques used in extreme climatic zones
b. To surface various architectural elements used traditionally for climate responsive approach
c. To discuss implementation of traditional knowledge in contemporary construction

2.4.2 Limitations:

a. The study is limited to hot and dry climate in Indian context
b. The study is limited to Jaipur as an example

3. Methodology

Pre-study	• Study the impact of Hot and Dry climate on Architecture
Traditional practices	• Analysis of architectural elements used in such conditions for mitigation
Case study	• Study of contemporary buildings in Jaipur for adaption of traditional knowledge
Primary data	• Insights from the professionals to understand the impact
Observation and discussion	• Readings from Literature review
Analysis	• Inferences from the study
Recommendations and way forward	• Conclusion

4. Literature Review

4.1 Jaipur: Challenges and traditional mitigation strategies

City of Jaipur is a heritage city and capital of Rajasthan. Having a rich history of architecture, Jaipur possesses lot of challenging issues as far as climatic conditions are concerned. Average temperature of the city reaches beyond 40 degrees Celsius during peak summers. **(*Figure 4*)**

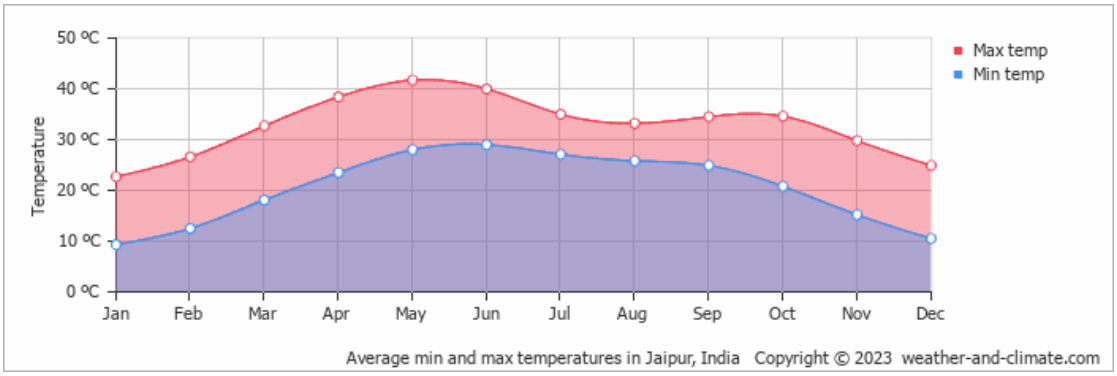


Figure 4. *Showing average temperature in Jaipur*
Source: average-temperature-india-jaipur.png (702×232)

Apart from the temperature escalation, Jaipur also suffers from Urban Heat Island Effect (UHI), biodiversity loss, water scarcity, air pollution and so on. (Mathew, 2023) Architecturally it is always thought-provoking region to design due to extreme weather conditions. Lot of historically important buildings present in the city are designed considering the special weather conditions. (Verma, 2023) Traditional buildings in the city and Rajasthan overall give a specific character as a result of the elements and materials used in those. The current trends in the city show high dependency on the mechanical ventilation and increased levels of energy consumption. Cultural heritage of the city is considered to be at stake due to this. Preserving the historical value and

cultural integrity in modern times has become a challenge which is majorly affecting the architectural essence of the city.

Traditionally the city architecture is considered to be rich as far as the design elements are concerned. Following are some of the elements which are seen commonly in the traditional buildings of the city.

4.1.1. Climate responsive design features of traditional Rajasthani architecture:

Courtyard / chowk

Courtyards or chowks are the prominent design features of Rajasthani architecture. Courtyard planning is considered to be very effective solution for hot and dry climate. It not only resolves the space planning and utilization but also mitigates issues like energy consumption, heat transfer, operative ventilation and passive design strategies. Scale and proportions of these courtyards are calculated precisely according to the usage and requirements of the function. Single, double, triple courtyards are commonly found in the traditional architecture of the region. Public buildings also show a presence of courtyard as a design element supporting public gatherings and related functions.

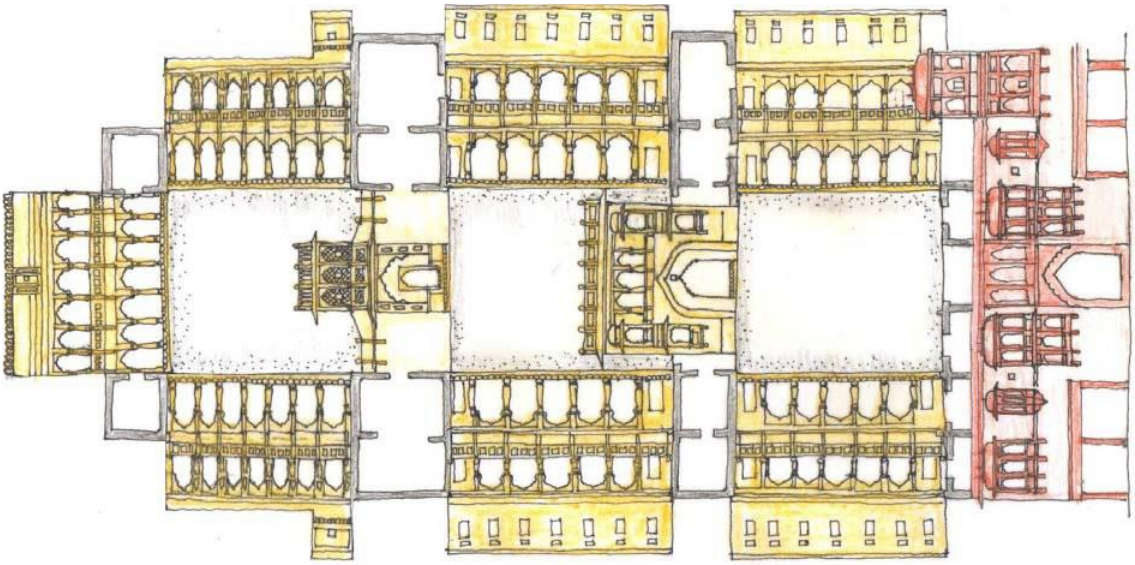


Figure 5. *Showing courtyard planning in Jaipur haveli (Natani ji ki haveli)*
Source: *Havelis and Haveli Temples – Jaipur World Heritage*

Jali or Latticed screens

Jali or Lattice screens are highly used and appreciated in Rajasthani architecture. The use of this feature is not only limited to the beautification but also plays an extremely important role in maintaining an ambiance. Controlling the internal temperature, passive lighting, privacy feature are some of the primary characteristics of these screens. (Azmi, 2022) Hawa mahal is a perfect example of the screens which is intended to allow gentle breeze to travel through a porous façade created by the lattice screens. Internal cooling of the building is achieved effectively by this design element. Jalis or lattice screens are considered to be a great source of energy efficient strategy.



Figure 6 *Showing Jali pattern in Amber fort, Rajasthan*
Source: *Stone Jali Windows at Amber Fort, Rajasthan, India - r/ArchitecturePorn*

Thicker walls

Thicker walls are primarily used in traditional Rajasthani built forms to fight with the extreme temperatures. These walls prevent a direct heat gain by not allowing heat to penetrate entirely through the façade of the building. Being one of the major components of passive design technique, it is an effective means of maintaining indoor environment cooler.

Building orientation and shading

One of the most strategically effective way of mitigating hot weather and high temperature conditions is building orientation placement. Using a building mass to create shaded areas is a best strategy a designer can have at a very early stage of design. A precise building orientation and massing study at the beginning of the design stage can resolve lot of issues which may arise at the operative stage of the building. Factors like sun path, massing proportion, usage of the building, user requirements, ambiance demand of the building are some of the key considerations that hold the entire onus.

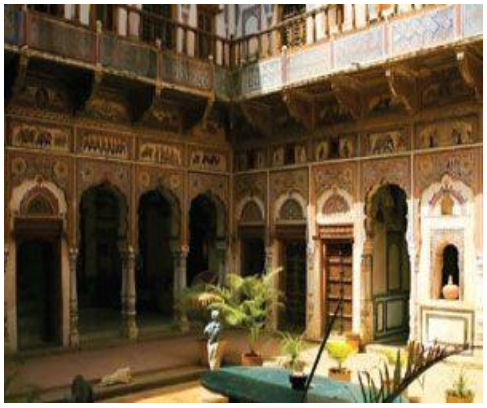


Figure 7. *Showing massing and shading importance of a building*
Source: *Architecture Of Rajasthan: Highlighting Aesthetic Sensibility & Architectural Marvels*

4.1.2. Use of materials:

Sandstone - Durable, local, low maintenance

Use of local materials is a common and sensible approach towards sustainability. As far as Rajasthan is concerned, it is rich in the availability of sandstone. Use of a stone not only gives a massive look to the structure but also provides a durable a low maintenance option. Many traditional buildings in Rajasthan have a sandstone used as a building material. Local availability of sandstone resolves various purposes other than sustainability character. It saves the transportation cost of the stone and as a result saves fuel. Secondly, local expertise is easily available and saves time to bring trained personnels from any other region. It also creates job opportunities for the locals.

(Baghel, 2024)



Figure 8 *Showing use of Sandstone in traditional Rajasthani architecture*
Source: *Amber Fort Near Jaipur, Rajasthan, India Editorial Photography - Image of mughal, majestic: 58103052*

Lime plaster - Breathable, antimicrobial, climate-friendly.

Indoor environment of the building matters the most when it comes to the comfort conditions. Aspects like relative humidity play a very important role in this. Breathability of the material for absorbing or releasing the atmospheric moisture holds the key and that is where materials like lime plaster have an upper edge over the other materials. (Chougula, 2007) Breathability, climate friendly nature of lime plaster carries a play in maintaining the comfort level inside. Use of lime plaster is seen majorly in the traditional buildings of Rajasthan. (Paralkar, 2020)



Figure 9 *Use of lime plaster in Rajasthan architecture*
Source: *Vernacular Wall Finish Techniques from Across India*

Terracotta tiles - Cool underfoot, locally made

Another material that is locally made and has got a climate responsive characteristic. Terracotta is a highly preferable material in hot and dry climatic conditions. Tiles, screens are common uses of the material. It is considered to be weather friendly material having no weathering effect in extreme conditions. Terracotta tiles are also known for

presenting a cool underfoot indoor effect in hot climatic conditions. Local availability, low maintenance, durability, aesthetical appeal are some of the interesting qualities of terracotta. Jalis made of terracotta are well-known for creating interesting patterns as well as filtering light.



Figure 10 *Showing use of terracotta in traditional Rajasthani architecture*
Source: *View of Vernacular Architecture of Jodhpur: A resilient approach to sustainable environment |* ***Shodhkosh:*** *Journal Of Visual And Performing Arts*

4.1.3. Cultural Aesthetics and Craftsmanship

Jharokhas, Chhatris, and Arches

Jharokha is a special design feature that is found in ancient Indian traditional architecture. Many Hindu, Mughal, Persian buildings are influenced by the feature as a main design element. Jharokhas were initially intended a means of ventilation. Later Rajasthani architecture created a special niche for it by adding it as a reflection of prosperity. Curved sandstone or marble with decorative lattice screens is a base design strategy for a typical jharokha. Magnificent look, intricate jali work, projection from main structure as a part of weather protection, privacy are some of the major intents of providing a jharokha. It became a culturally important element of Rajasthani architecture over the period of time.

Hawa mahal, City palace, Patwon ki haveli, Junagarh fort, Chittorgarh fort are some of the prominent examples of jharokhas in Rajathani architecture.



Figure 11. *Showing Jharokhas of Patwon ki haveli, Rajasthan*
Source: *Significance of Jharokhas in Rajasthan Architecture*

Traditional Craftsmanship

Traditional craftsmanship is considered to be a strength of Rajasthani architecture. Craftsmen of Rajasthan are known for their precise, intricate and delicate work which is unmatchable. The local strength of Rajasthan is appreciated all over in the world. The precision and accuracy along with extremely formulated details give a real essence of traditional design style of the region. The overall composition of Rajasthani architecture is governed by several factors amongst which craftsmanship is considered to be an extremely important aspect.

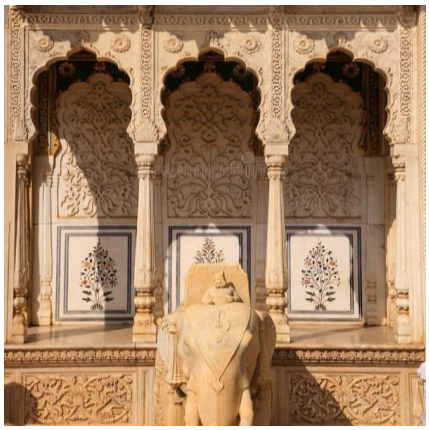


Figure 12 *Showing Rajasthani craftmanship*
Source: *1,179 Rajasthan Arches Stock Photos - Free & Royalty-Free Stock Photos from Dreamstime*

4.2 Case studies

4.2.1. Case Study 1: Pearl Academy of Fashion, Jaipur

The Pearl Academy of Fashion in Jaipur, India, is designed by a renowned architectural firm Morphogenesis. It stands as an outstanding example of contemporary architecture rooted in traditional wisdom. The project was Completed in 2008 and spans across an area of 11,745 square meters. The project was commissioned by the Pearl Academy of Fashion to stand as a leading educational institution for design. The building is situated in the hot and dry climate of Jaipur. To minimize on energy consumption the building integrates sustainable and passive design strategies while ensuring thermal comfort. The HVAC was designed by Design Centre, where they used innovative techniques combining modern environmental control systems with vernacular cooling methods such as courtyards, jaalis, water bodies and other passive systems. Climate-responsive campus is the outcome which harmoniously blends modern techniques and technology with regional architectural traditions. The project reflects the philosophy of Morphogenesis i.e working out contextual and sustainable design. (Morphogenesis, 2009)





Figure 13. *Showing form of the building*
Source: *www.archdaily.com*

The aim if the design concept is to create a cost effective and environmentally responsive campus that seamlessly blends functionality with sustainability. A strict budget of approximately 2500 per square foot was given to the architects to work out construction, interiors, furniture and landscaping. To meet this ambitious target the design had to depend on locally available materials, passive cooling strategies and traditional construction techniques eliminating conventional HVAC systems. This in-turn reduced the cost of the project enhancing the building's climatic/environmental performance and contextual relevance.

Form of the building:

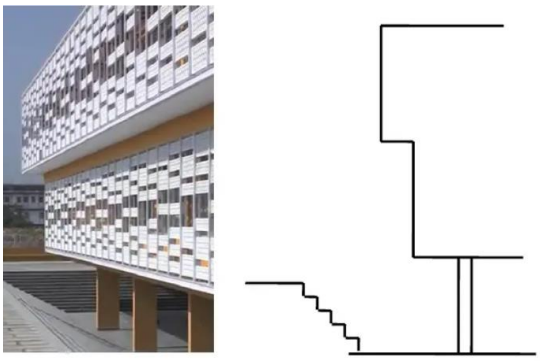


Figure 14: *Section of the building showing sunken courtyard*
Source: *www.archdaily.com*

The form of the building is a balanced integration of traditional Rajasthani architectural elements and modern design. The design of the building is inspired by the typology of traditional havelis and designed around a central courtyard, facilitating natural ventilation and daylight. The structure is covered with a perforated double façade, composed of jaalis and screens which filter harsh sunlight and reduce direct heat gain while maintaining visual connectivity with outside. The elevated massing of

the building allows the prevailing wind to enter the sunken courtyard below which helps to keep the surroundings cool even in the hot desert climate. The Integration of light and shadow, solid and void, gives a remarkable identity to the campus. The building is a contemporary interpretation of vernacular form adapted to the arid context.

Passive Cooling Control Methods:

Majorly two passive cooling strategies were adopted by Morphogenesis that helped to maintain a temperature of courtyards at a comfortable 27°C, even when outdoor temperatures rise to 47°C, establishing the building's exceptional climatic responsiveness. Firstly, the elevated building over the ground allows the prevailing wind to flow in around its edges and rise naturally through the central courtyards. Secondly the central stepped water body further cools the incoming air which circulates in the building. The stepped water body is fed by recycled water from on-site sewage treatment plant. A refreshing micro climate is created beneath the building because of the evaporative cooling from the stepped waterbody.

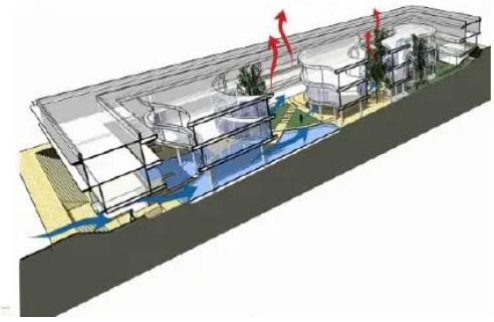


Figure 15: *Section of the building showing Passive cooling strategy*
Source: *www.archdaily.com*

Jaali: The building is protected from harsh climate by a double-skin facade which is inspired by the traditional 'jaali' work of Rajasthan a unique element of Rajasthani architecture. The double-skin facade acts as a thermal buffer, reducing heat gain enhancing the thermal comfort of the interior spaces of the building. computational shadow analysis is done to decide on the perforation density of the façade. The perforations are tailored to the orientation of each facade carefully optimized shading and daylight control. The distance of the outer skin is four feet from the main structure which helps to minimise direct heat gain from different fenestrations. Passive downdraft evaporative cooling is also used in the building to lower the temperature of the incoming air.

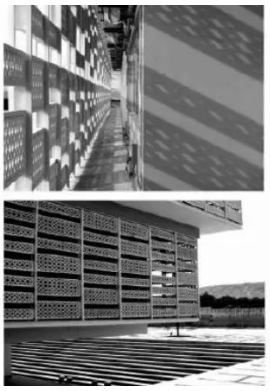


Figure 16 *Showing Jali*
Source: *www.archdaily.com*

Step Wells: The scooped-out space below ground level (known as underbelly) as a natural thermal sink because of the integration of the water body known as a step well. The central space is thermally enclosed on all sides and acts as a student recreation and exhibition area, serving as the central anchor of the campus. During night as the desert temperature drops, the stored heat gradually gets released in the surrounding which helps to maintain a thermally comfortable environment throughout.

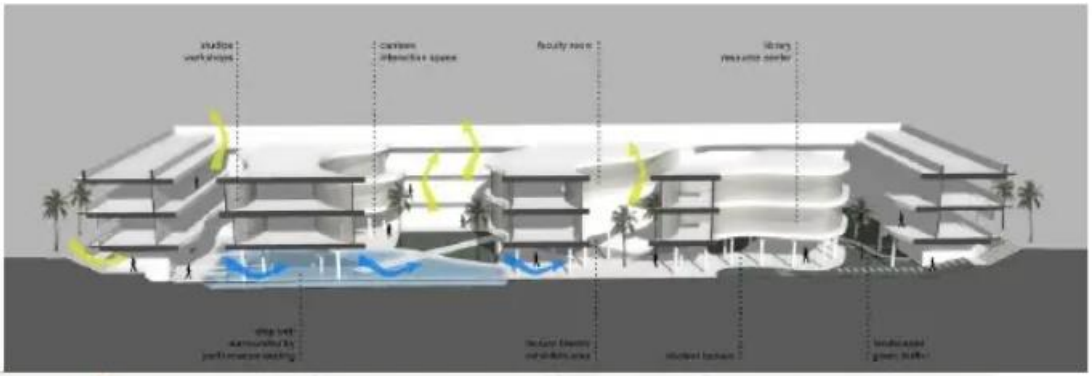


Figure 17 *showing Courtyard and Step Well*
Source: *www.archdaily.com*

Courtyard: The courtyard of the structure is designed in a curvilinear shape. The organic geometry of the courtyard was developed using computerized shadow analysis, which was designed to take care of the sun's movement throughout the day and in all the seasons. The classrooms and studios are well lit and ventilated through the courtyards. The self-shaded courts also helps to maintain the thermal comfort of the internal spaces naturally.

Roofs: The design of the roof of any building significantly influences heat gain, heat loss, natural ventilation and daylighting of the building. To reduce the heat gain the entire roof is covered with inverted earthen pots, which provides insulation and traps a layer of still air which reducing heat transfer and enhancing interior comfort.

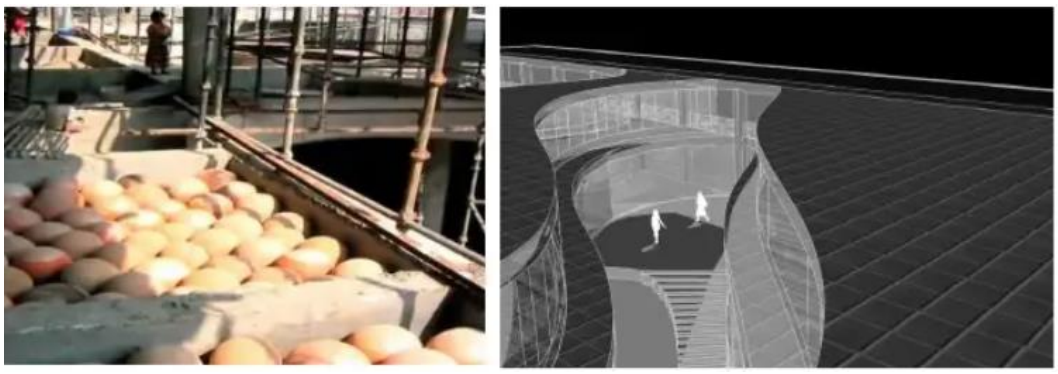


Figure 18. *Showing inverted earthen pots*
Source: *www.archdaily.com*

Rain water harvesting System: As a part of sustainable design approach the Pearl Academy of Fashion in Jaipur has an efficient rainwater harvesting system in place. The building is designed to capture and reuses rainwater mitigating the scarcity of the water in the hot and dry climate of the particular region. The rainwater is collected from the courtyard surfaces and the roof and channelled through a network of drains into underground storage tanks which is filtered and stored for later use. Water is also directed to the recharge wells to recharge the ground water level. The harvested water

is used for cooling systems, general maintenance and landscaping which reduces significant dependency on municipal supply. The case of Pearl Academy exemplifies how contemporary architecture can adapt traditional water conservation methods to meet the present-day sustainability goals in arid region.

4.2.2. Case Study 2: Jawahar Kala kendra, Jaipur

The Jawahar Kala Kendra in Jaipur, India is designed by Ar. Charles Correa. It is a striking fusion of modern architectural expression and traditional Indian wisdom. Government of Rajasthan commissioned the project as a multi-arts and cultural centre. The project represents Correa's vision in blending Indian traditional cosmological concepts along with contemporary architecture. The drawings of the project are inspired from the ancient Vastu Purusha Mandala. The drawings revolved around the cosmic order and alignment of architecture with celestial geometry. Spread across 9.5 acres the project was completed in five years. After completion in 1991, The campus functioned as a museum and a vibrant cultural hub that celebrated Indian traditional performances, art, craft while reflecting the architect's commitment to sustainability in terms of climate, Context and cultural identity. (Kadalassery)

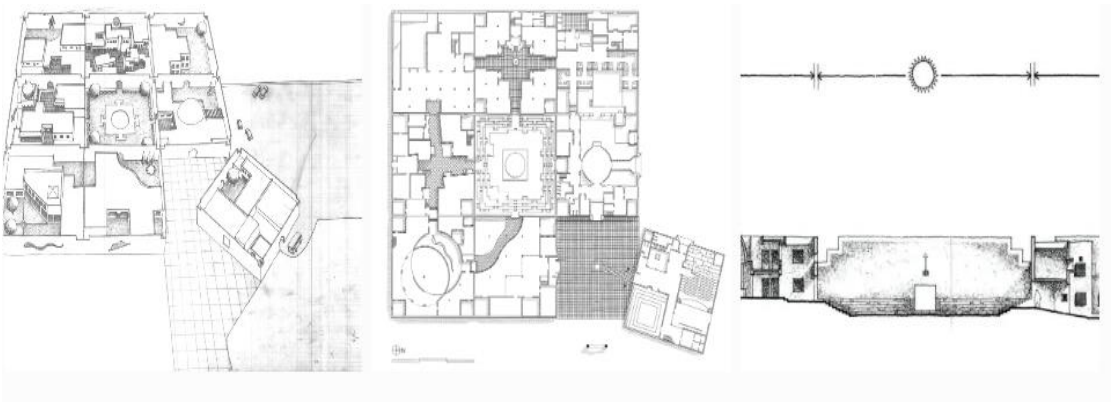


Figure 19. *Shows form of the building, Plan & Section of Jawahar Kala Kendra*
Source: *www.re-thinkingthefuture.com*

Form of the Building: The form of the Jawahar Kala Kendra in Jaipur is a response to hot and dry climate representing Charles Correa's philosophy of developing architecture in harmony with nature. The layout of the building is derived from the Navagraha or nine-square mandala. It is designed around a series of interconnected courtyards facilitating cross-ventilation, natural light with minimum direct solar gain. The narrow openings in the thick stone walls reduces heat absorption retaining much cooler interior spaces. The use of locally available sandstone not only merges the structure with Jaipur's architectural heritage but also helps in regulating temperature fluctuations. Passive strategies like recessed windows, Shaded corridors and pergolas further protect against the harsh desert sun light. Jawahar Kala Kendra becomes a climate-responsive model through these passive design strategies merging modern architectural expression with traditional wisdom creating contextually aligned spaces.

Passive Cooling Control Methods:

Jaipur is characterized by hot and dry type of climate with high temperatures and low humidity for most of the year. Charles Correa incorporated several passive cooling strategies to address these challenging climatic conditions in the design of the Jawahar Kala Kendra. The building is designed around a central courtyard, that bring in fresh air from all sides, promoting natural ventilation and there by reduces indoor temperature. Venturi effect is created with the help of small openings in the walls which increases air flow through the spaces enhancing thermal comfort without mechanical ventilation. In addition to that shaded corridors and use of pergolas allows diffused sunlight minimising exposure to direct sunlight reducing glare and heat gain. Correa's masterful integration of traditional wisdom and passive design principles are demonstrated through these elements resulting in an energy-efficient and climate-responsive built form.

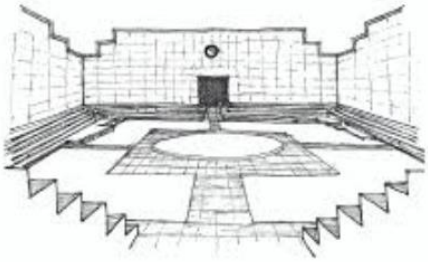


Figure 20 *Showing passive cooling through courtyard planning*
Source: *www.re-thinkingthefuture.com*

Thick Sandstone wall: One of the most defining features of Jawahar Kala Kendra which reflects Charles Correa's sensitivity to Jaipur's hot and dry climate is the thick stone wall. These walls are constructed out of locally available sandstone which has high thermal mass absorbing heat during the day time and slowly release it at night, thereby maintaining the indoor temperature. This process of natural insulation minimise heat gain and in-turn reduces dependency of mechanical cooling systems. The earthy tone of the sandstone also helps harmonizing with Jaipur's architectural context seamlessly blend with city's traditional pink and ochre colour. By using regional material and passive design strategies the building not only enhances occupant comfort but also strengthens the connection of environmental responsiveness and local craftsmanship.



Figure 21 *Showing thick Sandstone wall*
Source: *www.rethinkingthefuture.com*

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Recessed windows and narrow openings: In Jawahar Kala Kendra recessed windows and narrow openings are carefully designed by Correa to respond to the hot, dry environment of Jaipur. Direct solar radiation is minimized with the help of small windows fitted within in the thick stone walls. The surrounding masonry also provides natural shade and shadow throughout the day. The recessed windows help to keep the interior temperature cooler



Figure 22: *Showing recessed windows and window jalis for Venturi effect*
Source: *www.re-thinkingthefuture.com*

and comfortable by reducing the glare and heat gain. The narrow openings further create pressure differences enhancing natural ventilation with the help of Venturi effect, pulling in cooler air and releasing out warm air. All the above designed elements by Charles Correa's reflects his mastery over passive design blending modern environmental efficiency with traditional architectural wisdom to achieve energy efficiency and thermal comfort.

Pergola: In the Jawahar Kala Kendra the pergolas play a vital role in improving the building's climate-responsive design. The pergolas which are positioned along corridors helps taking in diffused sunlight of Jaipur's hot, dry climate casting rhythmic patterns of shade and shadow. This particular design element creates comfortable, semi-shaded transitional zones connecting indoor to outdoor reducing direct heat gain. A sense of openness and visual harmony is maintained through the pergolas along with thermal comfort, play of light and shadow, ventilation etc. By incorporating this traditional architectural element, Charles Correa effectively merges aesthetic expression with environmental functionality, demonstrating how shading devices can serve both climatic and experiential purposes in contemporary architecture.



Figure 23 *Showing difused natural light through pergola*
Source: *www.rethinkingthefuture.com*

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Rain water harvesting System: At Jawahar Kala Kendra rainwater harvesting system reflects Charles Correa's commitment to context based and sustainable design. As Jaipur is in hot and dry climate it receives limited annual rainfall so to conserve and manage water efficiently rainwater harvesting was thoughtfully integrated. Rainwater is collected from the building's courtyards and roof through a network of pipelines and collected to the underground storage tanks and further to the recharge pits. The stored water is then used for cooling plant, landscape, groundwater replenishment and maintenance reducing dependency on municipal water sources. The entire system demonstrates an eco-friendly approach suited to Rajasthan's dry conditions and also aligns with traditional Indian water management practices, such as tanks and stepwells. Through this integration, the Jawahar Kala Kendra becomes a model of how architectural design can harmonize with environmental sustainability and regional wisdom.

4.2.3. Survey data collection:

Primary data collection is mainly done to understand few things with respect to traditional architecture, elements used traditionally, impact factor of these elements, relevance of it in the modern scenario, use of the traditional techniques in modern architecture and effectivity of the same. The respondents of the data collections are architects who have seen, studied or experienced the case studies selected for this research. The aim of this data collection is to understand the capacity of traditional elements in contemporary architecture analysed by professionals in the field.

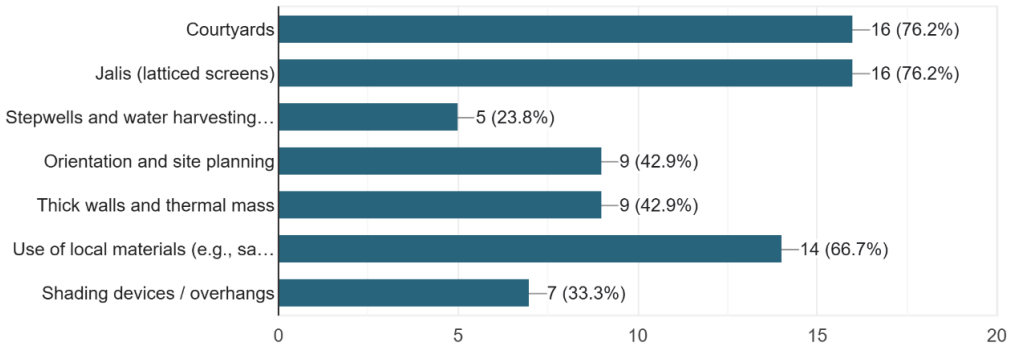


Figure 24 *Showing result for key Rajasthani traditional elements that contribute to climate resilience*
Source: *Author survey*

The ***Figure 24*** above reflects which traditional elements of Rajasthani architecture are effective in climate resilience. The intent of this data collection is to know the elements that hold an importance in climate responsive architecture.

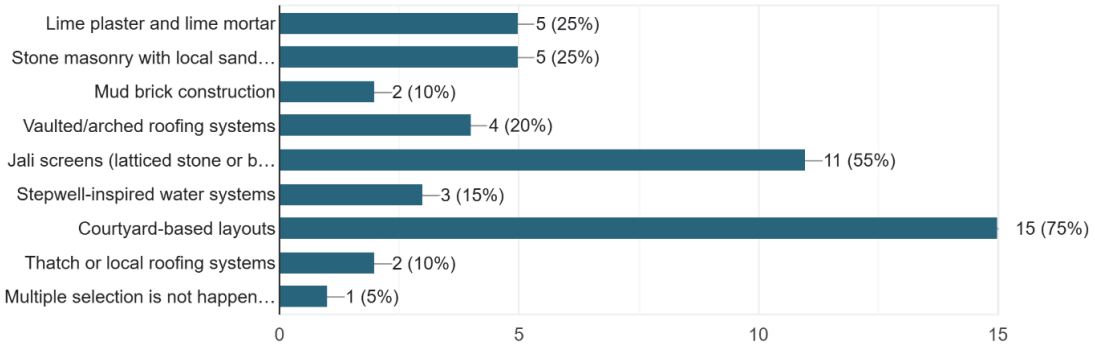


Figure 25 *Showing response to which traditional Rajasthani elements relevant to Moden climate responsive design*
Source: *Author survey*

The ***Figure 25*** above shows a response to which Rajasthani traditional technique holds an importance with modern climate responsive design. The intent of the data collection is to understand which traditional material have a potential to respond positively to the extreme climate.

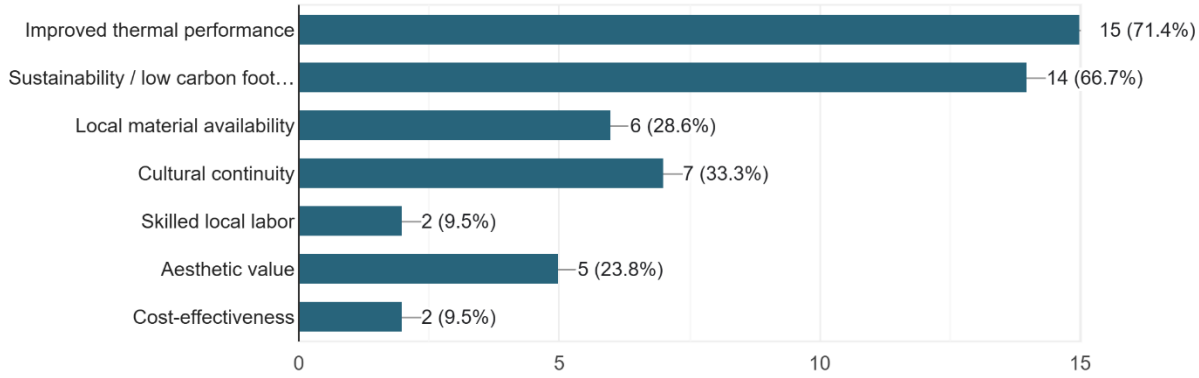


Figure 26 *Showing response to advantages of traditional construction in contemporary buildings*
Source: *Author survey*

The ***Figure 26*** reflects an opinion of respondents regarding advantages of using traditional construction methods in contemporary buildings. The response intends to understand the relevance of traditional architecture with contemporary style of design.

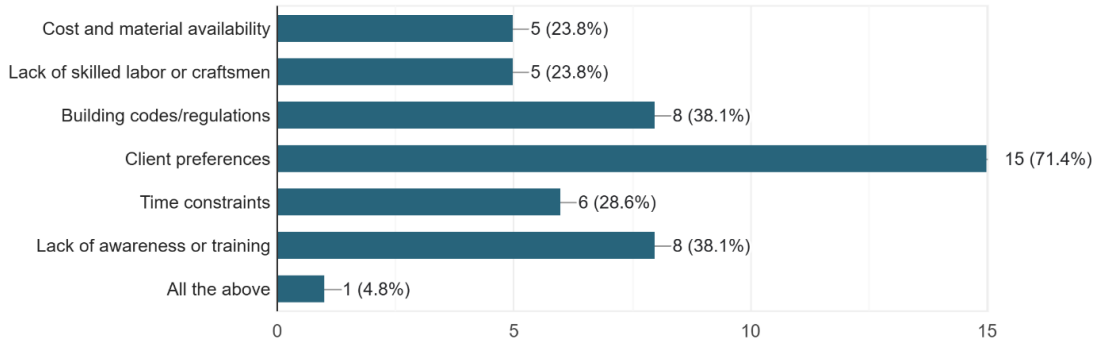


Figure 27. *Showing challenges of using traditional techniques in contemporary design*
Source: *Author survey*

The ***Figure 27*** reflects the challenges that professionals think could be an obstacle between incorporating the traditional methods and techniques in contemporary construction to achieve climate responsive design.

5. Observations and discussion:

5.1 Case Study 1: Through innovative climate responsive design the Pearl Academy of Fashion, Jaipur embodies an environmentally responsive, low-energy habitat. The campus seamlessly merge indoor and outdoor environments fostering interactive, multifunctional spaces and serves to a highly creative student community. Its Cutting-edge architecture arises from fusion of contemporary design principles along with traditional knowledge systems where the amalgamation of passive climate control strategies reduces reliance on mechanical systems enhancing thermal comfort of the interior spaces. Energy efficiency is the main focus of the project, which is fully self-sufficient in terms of energy efficiency and water supply. The institute strongly advocates sustainability through passive techniques, wastewater recycling system (through an on-site sewage treatment plant) and rain water harvesting system reinforcing its commitment to sustainable resource management.

5.2 Case Study 2: The observations from Jawahar Kala Kendra reveals how proficiently Charles Correa was successful in blending modern architectural perceptions with traditional Indian knowledge systems and planning principles to create a culturally vibrant and climatically responsive space. The architect's thorough understanding of Jaipur's hot, dry climate and local building traditions are reflected through the locally sourced sandstone, recessed openings, pergolas and the building's organization around interconnected courtyards. The planning fostered on an integrated approach with all passive design features such as daylighting, natural ventilation and rainwater harvesting systems long before it became a global architectural priority. The Kendra functionally serves as a cultural art and culture hub that supports traditional performances, exhibitions, creative workshops while maintaining a bridge between heritage and modernity. Overall Correa was successful in making Jawahar Kala Kendra a timeless

example of architecture creating built environments that is environmentally attuned, climate responsive, socially meaningful and spiritually enriching.

5.3 Primary Data Collection and Analysis

The survey data analysis on traditional Rajasthani architectural principles in contemporary design reveals that traditional design elements such as courtyards, jali screens, thick walls, and shading devices/overhangs play a significant role in achieving thermal comfort and energy efficiency in the region's hot and dry climate. The findings indicate that courtyard planning remains the most effective strategy for passive cooling, promoting cross-ventilation and creating shaded microclimates within buildings. Similarly, jali screens and perforated façades help regulate sunlight penetration while maintaining privacy and airflow, reducing dependence on artificial cooling systems. The use of locally available materials like sandstone and lime plaster enhances thermal mass, keeping interiors cooler during the day and warmer at night. The survey also reveals the challenges that professionals think could be an obstacle between incorporating the traditional methods and techniques in contemporary construction are majorly due to client preferences, lack of awareness or training and building codes or regulation. Overall, the survey underscores that these indigenous techniques—rooted in local wisdom and climatic understanding—continue to offer sustainable solutions for contemporary architectural practice in Rajasthan.

6. Recommendations and Conclusion

To enhance the environmental efficiency of buildings like the Jawahar Kala Kendra and the Pearl Academy of Fashion in Jaipur, future architectural projects should continue to carry forward the principles of passive design along with traditional wisdom. The main focus should be on integration of renewable energy systems, such as solar chimneys for improved ventilation, solar panels for power generation etc. Grey water recycling system and rainwater harvesting can solve the water issue in hot and dry regions. Energy demands can be reduced by adaptive shading elements, using locally available materials, low-embodied-energy materials. Additionally, participation in sustainable design practices and promoting community awareness has long term impact on environmentally responsive buildings. The above-mentioned strategies can direct the development of climate responsive architecture that remains both contextually rooted and future-ready.

In conclusion, both the Pearl Academy of Fashion and the Jawahar Kala Kendra in Jaipur exemplify and primary survey reveals that traditional building techniques are successfully implemented in the modern architecture. The results of these structures surface the importance of passive design techniques through traditional wisdom. Elements like Jali, Chattri, Courtyard planning, use of water bodies, Thick walls, Recessed windows, Lime plaster, Locally available stones are some of the examples of traditional Rajasthani architecture that are strategically used in the modern structures. Likewise, other climatic zones can also successfully implement the traditional construction techniques and elements in modern design without disturbing the aesthetic

and traditional value of the region. Traditional wisdom and modern design strategies can stand as an enduring model of sustainable architecture in India and also successful in terms of user-centric design — rooted in local wisdom, responsive to climate and context, and reflective of a deep respect for heritage and place.

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Traditional Knowledge, Local Practices, and Indigenous Construction Techniques: Anil Laul's Approach to Local Materials and Techniques

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Abstract: Ar. Anil Laul's architectural philosophy, which makes creative use of regional materials and conventional building methods, places an emphasis on affordability, sustainability, and contextual relevance. His creations demonstrate a profound concern for ecological harmony, social housing, and community empowerment through the accessibility and responsiveness of architecture to local requirements. Using mud, stone, lime, bamboo, and fly-ash blocks, as well as reimagining methods like infill slabs, rat-trap bond masonry, and passive cooling systems, Laul showed how architecture might be economical and ecologically conscious. From affordable housing to institutional buildings, his projects are real-life examples of how indigenous knowledge combined with contemporary design sensibility can produce climatically appropriate, structurally sound, and culturally entrenched structures. This research will focus on the significance of using regional resources and building techniques to address the issues of cost and sustainability in modern architecture, which is further supported by Ar. Laul's legacy.

Keywords: Indigenous practices; low-cost home; sustainable architecture; filler slab; rat-trap bond; passive cooling; local materials; construction methods.

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1. Introduction

In an era marked by rapid urbanization, environmental degradation, and escalating construction costs, the need for sustainable and contextually grounded architectural practices has become increasingly critical. Architects and designers across the world are revisiting traditional wisdom and regional practices to develop solutions that are both environmentally responsible and economically viable. Within this framework, **Ar. Anil Laul** emerges as a visionary whose work exemplifies the integration of **indigenous knowledge, local materials, and sustainable building techniques** in contemporary architectural practice. Laul's philosophy redefines modern architecture by grounding it in **ecological sensitivity, social equity, and contextual appropriateness**. His extensive body of work demonstrates how architecture can respond meaningfully to **local climates, resources, and community needs** without compromising on design innovation or structural efficiency. Through the creative application of **materials such as mud, lime, stone, bamboo, and fly-ash blocks**, and the reinterpretation of traditional methods like **filler slabs, rat-trap bond masonry, funicular shell roofs and passive cooling systems**, Laul presented architecture as a tool for **empowerment, affordability, and environmental protection**.

This research paper delves into the **philosophy and practice of Ar. Anil Laul**, examining how his approach serves as a model for addressing contemporary challenges of **cost-effectiveness and sustainability**. By exploring his contributions to low-cost housing and institutional architecture, the study underscores the continued relevance of Laul's legacy in shaping a future where modern architecture remains deeply connected to its **regional, cultural, and ecological roots**.

1.1 Research Methodology Adopted

The research adopts a qualitative and analytical methodology based on literature review and comparative case study analysis. Primary and secondary sources—including books, archival material, project documentation, and scholarly publications, were reviewed to establish the theoretical framework. Selected projects representing different typologies were analyzed using parameters such as material use, construction technique, structural efficiency, climatic response, and cost-effectiveness. Comparative tables and diagrams were used to synthesize findings and interpret how traditional knowledge was reimagined through modern architectural innovation, highlighting Anil Laul's contribution to sustainable and contextually grounded design practice.

2. His Philosophy and Design Ideology

1) He is best known for his subtle, organic, yet geometrically balanced architectural forms with design philosophy emphasizes clarity, precision, and attention to detail which often blends with traditional techniques and contemporary aesthetics, creating designs that are both timeless and contextually rooted.

2) Laul once shared, *"I have chosen to do re-search, not research as we know it,"* reflecting his belief in revisiting and reinterpreting traditional wisdom. He believed that good design is simple and requires a harmonious balance between nature's generosity, traditional knowledge, and modern technological advancements. He placed strong emphasis on cost-effective construction without compromising the aesthetic and functional quality of a building.

3) According to him, the construction technologies applied in high-income housing can also be effectively used in slum rehabilitation, proving that good design transcends economic boundaries. He built low-cost, low-energy, climatically responsive, and aesthetically appealing houses using recycled materials—always keeping the human scale and real needs of people at the center.

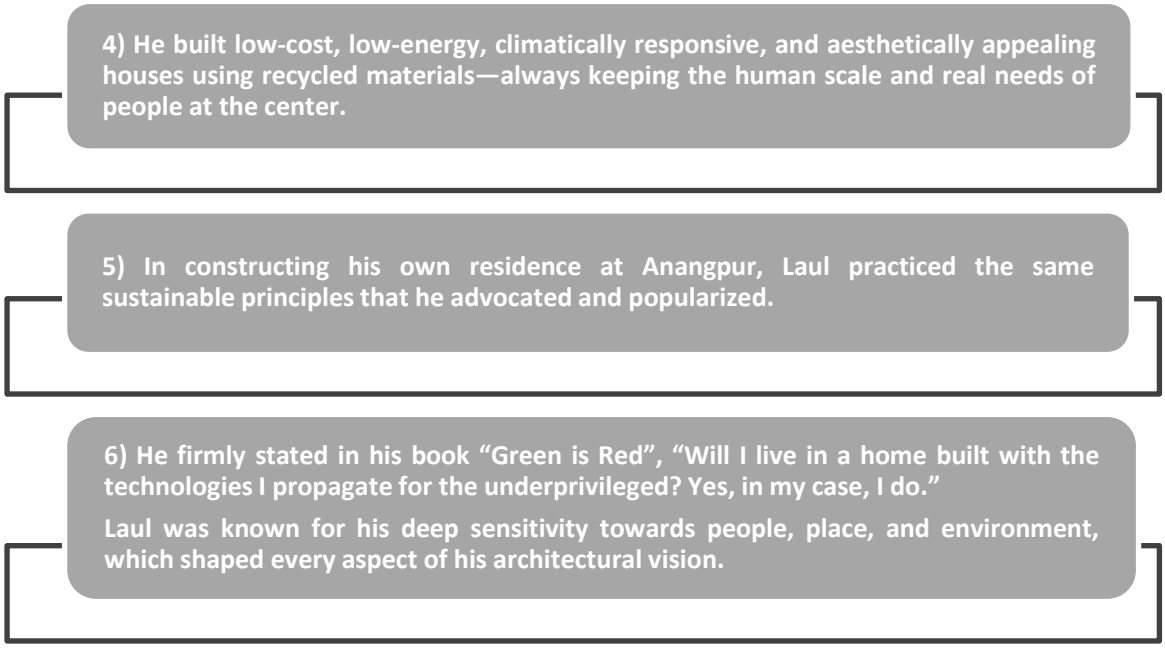


Figure 1. *Refers to Laul's Ideology and philosophy*
Source - *Author, from the book* ***Green is Red***

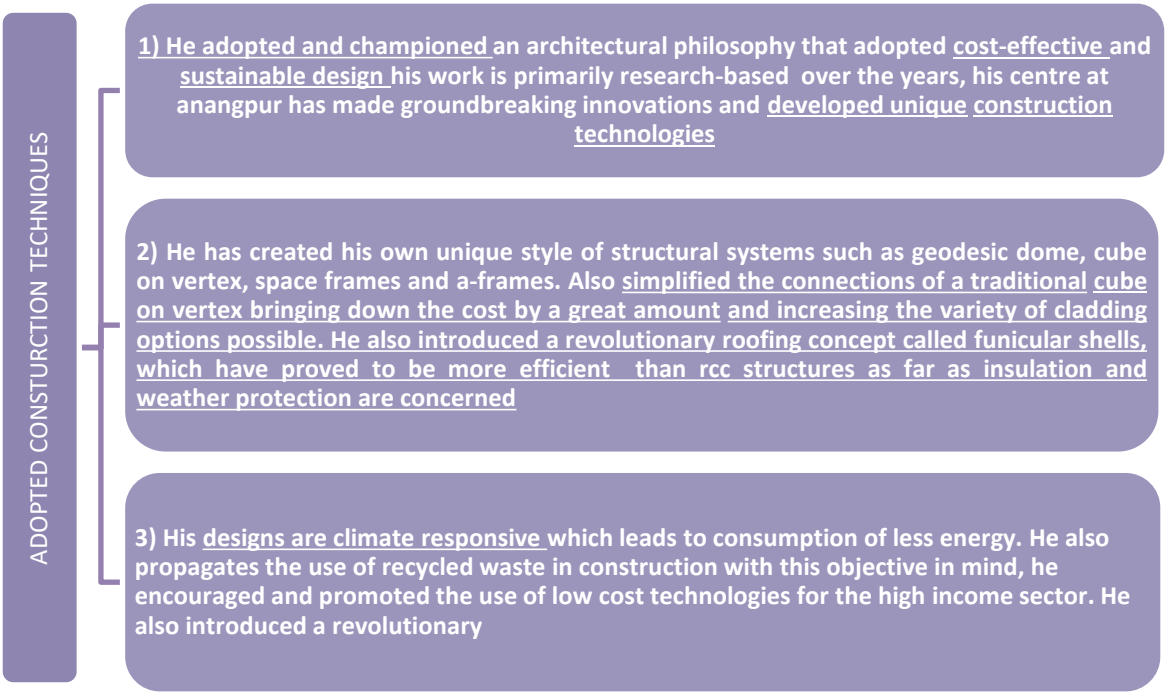


Figure 2 *Refers to Laul's adopted construction techniques*
Source- *Author, from the book* ***Green is Red***

Some of the adopted and practiced construction techniques used by Mr. Laul were: -

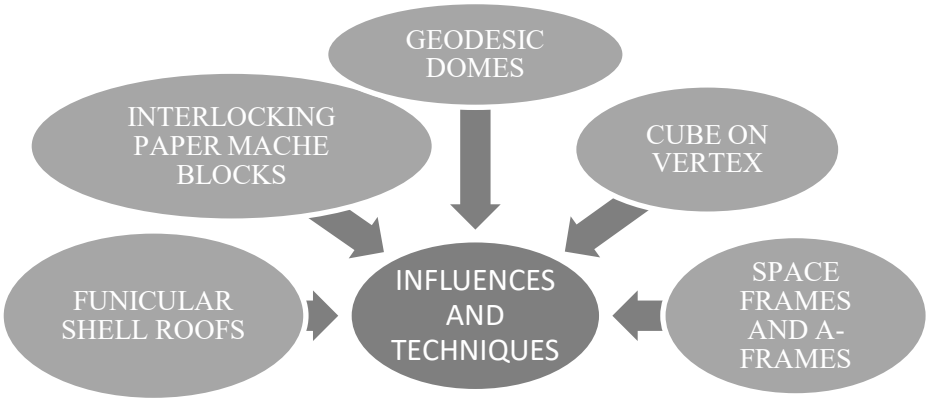


Figure 3. *Refers to Influences and techniques*
Source- *Author, from the book* ***Green is Red, Threads of Sustainability***

2.1 Funicular Shells

Funicular shells are thin, curved structures that follow the natural path of compressive forces, achieving maximum strength with minimum material. Derived from the principle of the "funicular line," these shells efficiently distribute loads without bending stresses. Architects like Ar. Anil Laul used them to create climate-responsive, low-cost roofs using local materials such as brick or ferrocement, combining engineering precision with organic form. A detailed comparative analysis gives a clear picture of how funicular shell roofs are more sustainable in nature.

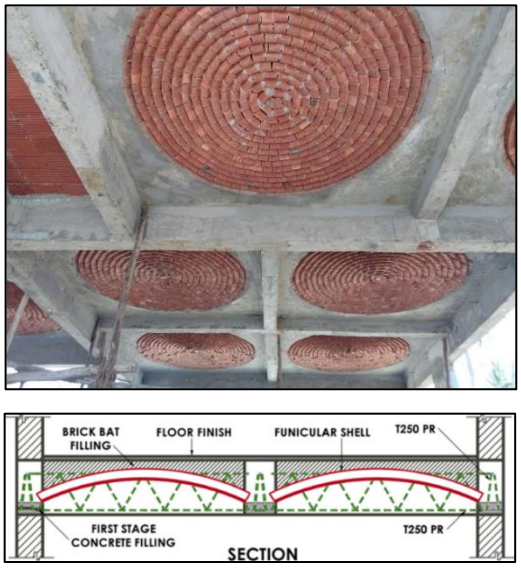




Figure 4. *Refers to funicular shell roofs -construction techniques*
Source*-https://architecture.live/prof-anil-laul-a-pioneer-of-indigenous-architecture-in-india-pappal-suneja*

A) FUNICULAR SHELL ROOF-COMPARATIVE ANALYSIS				
Parameter	**Deepalaya School**	**Primary School, New Dudhail**	**Pushkarna Residence**	**Anangpur Building Centre**
Scale / Function	Educational – Urban	Educational– Rural	Residential	Demonstration / Research
Span Type	Small modular shells	Small modular shells	Medium–large expressive shell	Prototype modules
Material	Brick masonry shell	Brick+hollow blocks	Brick+ ferrocement finish	Mixed materials for training
Constructio n Method	Repetitive modular centering	Local Manual centering	Custom geometry with structural tie	Teaching aid
Design Intent	Cost efficiency + thermal comfort	Self-help construction	Spatial and aesthetic expression	Skill dissemination
Outcome	Rhythmic facade, daylight comfort	Community empowerment	Sculptural spatial quality	Knowledge transfer
Site Images	NA	NA		

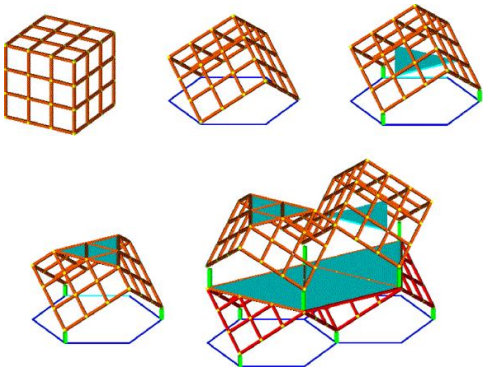
Conclusion - Funicular shell roofs demonstrate structural efficiency, material economy, and design versatility. Their adaptable geometry—square, rectangular, triangular, or trapezoidal—offers flexibility in architectural design. Constructed using locally available waste stone, they minimize the use of high-energy materials like steel and cement, promoting sustainable building practices. The arch action ensures uniform load distribution, enhanced seismic performance, and freedom in wall placement. These roofs require no surface finishes, are easily built with semi-skilled labor, and provide excellent insulation and weather protection at low cost. Overall, funicular shells offer an efficient, eco-friendly, and aesthetically expressive alternative to conventional RCC roofing systems.

2.2 Geodesic Domes



Anil Laul's work with geodesic domes built at his Anangpur building center reflects his focus on low-cost, sustainable housing. He combined traditional techniques with modern geometry, using recycled materials to create cost-effective, aesthetic, and environmentally responsive structures. His designs often integrated geodesic domes with systems like cube-on-vertex and space frames for structural and visual harmony.





2.3 Cube on Vertex

The **Cube on Vertex** technique involves the rotation of a cube onto one of its vertices, generating dynamic spatial compositions and a distinct sense of volumetric equilibrium. This geometric manipulation introduces **visual dynamism and spatial diversity** within architectural form. Architect **Anil Laul** employed this principle in projects such as the **Primary School at New Dudhai, Gujarat**, and the **Deepalaya School, New Delhi**. Through this approach, Laul challenged conventional orthogonal layouts, promoting **natural light penetration, enhanced spatial hierarchy, and visual engagement** while preserving **structural clarity and simplicity**. The technique exemplifies how geometry can be strategically utilized to balance **aesthetic innovation and functional pragmatism which is explained through comparative analysis below**.



Figure 5. *Refers Cube on vertex*
Source- *Author, from the book* ***Green is Red, Threads of Sustainability***



Figure 6 *Refers to funicular shell roofs -construction techniques*
Source- *https://www.scribd.com/document/369720156/Anil-Laul-pdf*

B) Cube-on-vertex -comparative analysis		
Criteria	**Primary School, New Dudhai, Gujarat**	**Deepalaya School, New Delhi**
Concept & Form	The *Cube-on-Vertex* form is used to create dynamic, interlocking classroom volumes that respond to the desert climate. The geometry aids in achieving structural stability with minimal materials.	The *Cube-on-Vertex* structure is adapted to an urban context, providing visual interest and spatial variation within a compact site. The geometric form enhances natural lighting and ventilation.
Climate Response	Designed for hot, arid conditions—thick walls and shaded courtyards reduce heat gain while allowing natural cooling.	Oriented to optimize cross-ventilation and daylight, addressing the humid subtropical climate of Delhi.
Material Use	Locally available stone, brick, and waste materials used to ensure sustainability and cost-efficiency.	Recycled materials and locally sourced components used to reduce construction costs and environmental impact.
Structural Expression	The tilted cube geometry creates volumetric depth and visual rhythm while maintaining simplicity in construction.	The cube form is expressed as a modular system, facilitating expansion and adaptability for changing educational needs.
Spatial Environment	Spatial variation promotes creativity and interaction among students, integrating open-air learning spaces.	Compact yet flexible spaces encourage efficient use of area and enhance visual connectivity across levels.
Overall Approach	A rural prototype emphasizing low-cost, climate-responsive architecture.	An urban interpretation focusing on adaptability, modularity, and environmental sensitivity.

Both schools exemplify Ar. Anil Laul's Cube-on-Vertex approach, integrating geometry, sustainability, and human-centered design. While the **New Dudhai School** reflects a rural, climate-adaptive model, the **Deepalaya School** showcases urban adaptability within limited space—both embodying Laul's philosophy of resource-efficient, context-responsive architecture.4**. Space Frames and A-Frames.**

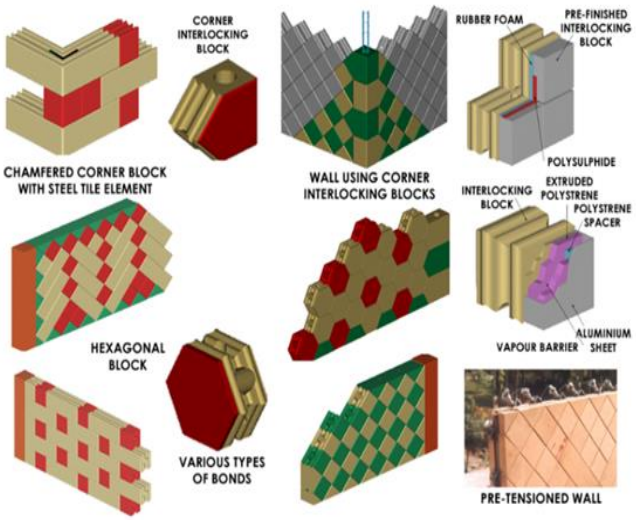


Figure 7- *Hollow Core interlocking blocks*
Source- *Red is green 2013*

2.4 Hollow Core interlocking blocks

Architect Anil Laul pioneered the development of hollow interlocking blocks as part of his pursuit of low-cost, sustainable architecture, notably applied in projects such as the Anangpur Building Centre. These blocks were conceived to ensure construction efficiency and structural stability, while promoting the use of indigenous and recycled materials.

Laul also introduced other innovative building techniques, including the "Ram Lochan Tile," as well. The extensive use of hollow interlocking blocks is clearly reflected through the comparative analysis of two of his completed projects.

Paper mache blocks can be customized and designed into various shapes and sizes. The hollow-core interlocking blocks used for walling in the project were made from paper-mache. The thermal efficiency of these blocks kept the interiors so cool that fans were unnecessary even during June. inauguration. The children were delighted by colourful, homely environment and the pleasant ambience inside the school.



Figure 8. *Steps for making Paper Mache blocks hollow core interlocking blocks*
Source- *Red is green 2013*

B) Comparative Analysis: Hollow Core Interlocking Blocks		
Criteria	**Bioclimatic School, Vadodara (Gujarat)**	**Pushkarna Residence, Chandigarh**
Concept & Purpose	Developed as a cost-effective and sustainable solution for educational infrastructure. Focused on rapid construction and ease of assembly using modular interlocking blocks.	Used to achieve a structurally efficient and environmentally conscious residence with minimal reliance on cement mortar and plaster.
Design Approach	The modular system enabled quick classroom construction with precise alignment and minimal skilled labour.	The technique was adapted for residential scale, creating aesthetic brick patterns and ensuring structural stability.
Material Use	Locally produced hollow interlocking blocks reduced transportation and material costs, promoting sustainability.	Blocks made from local materials, providing thermal comfort and reducing embodied energy.
Construction Technique	Dry construction system—blocks interlock without extensive mortar use, speeding up execution.	Same system used with customized detailing for openings, services, and finishes suited to a home environment.
Aesthetic & Function	Exposed block texture adds character while maintaining low maintenance. Natural ventilation and lighting enhance the learning environment.	Exposed masonry provides a raw, earthy aesthetic and acts as thermal insulation for interior comfort.
Environmental Response	Passive cooling through hollow cores and minimal use of plaster enhances energy efficiency.	The hollow cores reduce heat transfer, keeping interiors cooler and reducing energy demands.
Overall Impact	Demonstrates how modular block systems can make educational buildings economical, durable, and climate responsive.	Illustrates adaptability of the same technique for domestic use while maintaining aesthetics and sustainability.
Site Images	 	 

3. Research findings

The research on Ar. Anil Laul's approach to traditional knowledge, local practices, and indigenous construction techniques reveals how his architectural philosophy was far ahead of its time in addressing the intertwined challenges of sustainability, affordability, and social equity. His design ideology reflects a deep respect for the wisdom embedded in vernacular architecture, coupled with an innovative reinterpretation of these methods to meet modern needs. Laul's architectural practice revolved around the belief that true sustainability lies in contextual responsiveness—in designing buildings that grow from their surroundings, use locally available materials, and meet the socio-economic needs of the community. His projects demonstrate how traditional materials like mud, stone, lime, bamboo, and fly ash blocks, when intelligently employed, can create structures that are not only environmentally sustainable but also economically viable and culturally rooted.

3.1 Research gap with objectives

Despite increasing interest in sustainable and vernacular architecture in India, traditional construction techniques are often examined as historical precedents or isolated technical solutions. Although Ar. Anil Laul is widely recognized for pioneering indigenous, low-cost, and climate-responsive architecture, existing literature largely remains descriptive, focusing on individual projects or biographical narratives. There is limited systematic and comparative research evaluating how Laul integrated traditional knowledge with modern structural innovation across diverse building typologies, as well as a lack of performance-based assessment of his methods in terms of material efficiency, thermal comfort, construction economy, and social impact.
This study aims to critically analyse Anil Laul's architectural philosophy and construction practices with emphasis on the use of indigenous materials and techniques. The objectives are to examine his design ideology, identify key construction systems employed in his projects, conduct a comparative analysis of selected case studies, and evaluate the sustainability performance and contemporary relevance of his approach for low-cost and climate-responsive architecture

4. Integration of traditional techniques with modern innovation

4.1 Funicular shell roofs

Laul's funicular shell roofs show his skill in combining structure and design. These thin, curved roofs follow natural force paths, needing little material or reinforcement. They stay cool, reduce heat, and offer strong yet lightweight shelter—perfect for India's

climate. Projects like Deepalaya School, Primary School at New Dudhai, and Pushkarna Residence reveal how Anil Laul balanced beauty, efficiency, and environmental care. with Geodesic Domes and Structural Geometry. At Anangpur Building Centre, Laul used geodesic domes to create lightweight, self-supporting, and low-cost structures. By combining domes with systems like space frames and A-frames, and using recycled materials, he proved that geometry and sustainability can go hand in hand.

4.2 Cube-on-vertex technique'

Used in the Primary School at New Dudhai and Deepalaya School, the cube-on-vertex form improved light, ventilation, and spatial quality. It adapted well to both rural and urban settings—keeping interiors cool and construction simple—while showing how one design idea can serve multiple contexts sustainably.

4.3 Hollow core interlocking blocks

Developed at the Anangpur Building Centre, these modular blocks made construction faster, cheaper, and eco-friendly. Used in the Bioclimatic School, Vadodara, and Pushkarna Residence, Chandigarh, they offered insulation, reduced material use, and required no plaster, making them ideal for affordable, sustainable housing.

4.4 Space frames and a-frames

Laul's use of space frames and A-frames reflected his focus on modular, lightweight, and low-cost structures. These systems spanned large spaces efficiently and, when combined with local materials, created climate-responsive and resource-saving designs.

4.5 Broader implications of laul's approach

Ar. Anil Laul's work transcended the boundaries of architecture—it became a social and educational movement. Through Anangpur Building Centre, he not only developed prototypes and techniques but also trained local masons, engineers, and students, empowering communities to build sustainably with their own hands. His belief that "architecture should belong to the people" reflects his vision of a decentralized, participatory model of design where knowledge sharing and self-reliance replace dependence on industrial construction systems. Anil Laul's projects consistently demonstrate that sustainability is not a style but a process—a continual engagement with context, climate, and community. His designs were guided by environmental performance rather than ornamentation, resulting in structures that breathe, respond,

and age gracefully within their settings. The seamless blending of form, function, and ecology in his work represents a powerful alternative to the energy-intensive and homogenized architectural practices that dominate much of contemporary construction.

5. Conclusion

The comprehensive analysis of Anil Laul's architectural methods reveals a holistic vision rooted in traditional wisdom and modern relevance. His legacy underscores the potential of indigenous knowledge systems to inspire contemporary sustainable architecture. By combining structural innovation, local material use, and climatic sensitivity, Laul proved that sustainable architecture is not just an environmental necessity but a cultural and ethical responsibility. His work continues to serve as a blueprint for future architects, educators, and policymakers who seek to create built environments that are affordable, resilient, and contextually meaningful. In essence, Anil Laul's architecture embodies the philosophy that progress in design must not come at the cost of tradition or ecology—it must evolve *through* them.

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Sacred Hydrology: Traditional Water Tanks and Water Management Practices in Cuddalore, Tamil Nadu

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Abstract: Temple tanks and water management systems in the Cuddalore district are a community-driven activity and an ecologically adapted method to connect to nearby rivers, and represent a sacred cosmology. Centred around the Chidambaram Natraja temple and extended through canals and ooranis, these systems sustained ritual life, secured water supply for agriculture, and maintained groundwater balance in a monsoon-dependent, flood-prone region. A religious meaning was integrated with an ecological function, reflected in indigenous hydrological intelligence. Urbanisation and colonial interventions changed the old networks which led to siltation, deterioration of water quality and a functional decline. The current restoration initiatives have prioritised desilting, encroachment removal, community engagement, bund strengthening, ecological planting and heritage conservation. This study aims to document the ecological and hydrological impacts alongside the socio-cultural aspects of the restoration effects and evaluate its effectiveness in enhancing resilience. The methodology includes a quantitative evaluation of water quality, storage capacity, groundwater recharge rates and biodiversity, as well as an evaluation of legal urban water management frameworks and uses comparative case analysis. The research explores how integrating insights from traditional water systems in current municipal practices offers comparative perspectives on climate-adaptive urban infrastructure in Cuddalore and Tamil Nadu.

Keywords: Sacred hydrology; Traditional water management; Climate-adaptive infrastructure; Urban water resilience

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1. Introduction

Historically, typical Indian settlements are located or evolved around temples and sacred waterbodies, where almost every temple settlement has a temple tank, which served as an integral part of the region's culture and hydrology. Temple tanks act as a nucleus to community life and sustain annual festivities and rituals while also hosting traditional architectural knowledge (Madhavi Ganesan, 2008). Traditional water management practices remain central to sustainable strategies across India, integrating local knowledge with modern design frameworks (Jain et al., 2024; Verma et al., 2025). Water and worship have shared a symbolic relationship in the culture of South India, where these temple tanks, locally known as *kulams* (pond or water reservoir) or

teerthams (sacred or ritual water), are more than just spaces for rituals; they hold a significant part in the local community's belief and identity while also serving as a hub for social gathering and ecological activities hence representing utilitarian and spiritual functions within a temple complex (Amirthalingam, 2009). The temple tanks in Tamil Nadu form a part of an intricate hydraulic landscape that is shaped by regional climatic and local cultural conditions (Weiz, 2006), and the hydrology reflects a long-standing tradition of integrating ecology and architecture, along with ritual practices (Chakrabarti & Amirthalingam, 2020).

The water management systems attached to the religious beliefs were a major motive to create these tanks. Traditionally, these tanks were built to function as stormwater buffers, storage tanks, microclimatic regulators, and aquifer recharge zones. They represent traditional water management infrastructure whose ecological importance and intelligence remain under-recognised in contemporary urban planning (Ariza et al., 2007; Madhavi Ganesan, 2008). Numerous temple tanks across Tamil Nadu have experienced a decline due to colonial land policies, urban encroachment, pollution, siltation and a disconnection from feeder is observed in the case of Cuddalore, where degradation of the temple tanks has increased vulnerability to floods and diminished water security locally (EFI, 2020).

The study explores the role of temple tanks in the present day as ritual sites and urban infrastructure by integrating quantitative data with secondary documentation and community perception. It focuses on six tanks in and around Chidambaram and within Cuddalore. Three restored and three non-restored tanks have been chosen to comparatively assess their spatial, hydrological and socio-cultural dimensions. The study emphasises the need and necessity of accurate and renewed documentation in order to position traditional water management systems like kulams as a framework for flood mitigation and as a preservation of sacred hydrology and the region's heritage and cultural identity.

2. Literature Review

2.1. Regional Setting

The temple tanks of Tamil Nadu have historically served a variety of purposes, including water storage, ecological services and ritual functions have emphasised a perception of an ecosystem, highlighting community engagement in maintenance. These systems reflect a deep ecological consciousness, balancing ritual sanctity and sustainable hydrology (Bimrah & Saizen, 2025; Saravanan, 2020). Siltation, encroachment, and poor water quality are results of colonial and post-colonial urbanisation's disregard for the native water networks. Colonial land tenure systems, modern drainage infrastructures, and privatisation led to the neglect of these tanks.

2.2. Temple Tanks as Hydro-Social Infrastructure

Temple tanks functioned as multi-purpose water systems that urban design with hydrological settlements while retaining basins that controlled flooding, recharged shallow aquifers and supported irrigation networks (Karthi & Balamurugan, 2017; Madhavi Ganesan, 2008). The core of hydraulic systems in temple towns, especially in Tamil Nadu and Andhra Pradesh, has interconnected networks, often linked through channels, and the tanks exemplify the concept of hydro-social infrastructure, where water and belief, along with the built form, are mutually sustaining while reflecting ecological consciousness (Bimrah & Saizen, 2025; Saravanan, 2020). A similar system of integrative networks exists in Sri Lanka. The traditional tank cascade system demonstrates parallel models of hydrosocial infrastructure, depicting how traditional water networks created relationships between ecology, culture and settlements (Gunasena & Nianthi, 2024).

Environmental studies have identified temple tanks as vital nodes in pond ecosystems, offering hydrological and biodiversity benefits while simultaneously representing human-dependent landscapes that sustain ecological diversity along with social identity (Farina, 2022; Kumar & Padhy, 2015).

2.3. Decline and Disconnection

The traditional water management systems and structures have faced a major decline due to land revenue policies, canal irrigation projects, urban encroachments and colonial transformations (Karuppaiya, 2025) influencing present-day tank management (Saravanan, 2020). Numerous temple tanks in Tamil Nadu have dried up or been converted, degrading the area's culture and heritage (EFI, 2020). Depletion of groundwater and loss of catchment linkages of a region further reduced the recharge capacity and ability (Ariza et al., 2007).

2.4. Restoration and Community Efforts

Recent restoration efforts in cities of Tamil Nadu, namely, Chennai, Madurai and Thanjavur have resulted in a measurable increase in water quality, biodiversity and storage capacity. The EFI Chidambaram project is a notable effort in the district of Cuddalore that involved volunteers and the community in the restoration of temple tanks, along with the removal of over 400 encroachments, desilting the tanks and ecological planting to revive the heritage structure and system, while also trying to improve the biodiversity (EFI, 2020).

3. Study Area and Tank Selection

3.1. Regional Setting

The coastal wetlands of Tamil Nadu, including both temple tanks and mangrove regions of the state, form interconnected hydrological corridors that sustain water recharge (Gnanappazham et al., 2025). The district of Cuddalore, situated along the coastal belt of Tamil Nadu is home to a rich network of temples and temple tanks,

several of which remain neglected and undocumented. On the contrary, contemporary sustainable initiatives in nearby Auroville exemplify experimental models for decentralised water management across the region (Nagy, 2021).

Located between the Vellar and Gadilam rivers, the district of Cuddalore receives about 1,300 mm of rainfall each year. The district receives maximum rainfall during the northeast monsoon, making the district more susceptible to floods due to its flat terrain and growing population. Due to the loss of historic temple tanks, obstruction of natural water drainage channels, and a rapid increase in land use have substantially diminished the area's water absorption capabilities, increasing vulnerability to floods and the decline of groundwater resources.

3.2. Selected Temple Tanks

The measurements of the tank area and elevation were extracted using satellite imagery (2024) and data on restoration status derived from EFI documentation (EFI, 2020) and local administrative reports. Given the absence of standardised on-site documentation, satellite-based proxies were used to approximate storage and spatial capacities and conditions.

Table 1. Area, restoration status and elevation of temple tanks

Tank Name	Restoration Status	Area (m²)	Elevation (m)
Padaleeswarar	Restored	704.15	43.0
Sivagangai	Restored	4,295	26.0
Ilamaiyakkinar Koil	Restored	7,891.8	23.0
Vishveshwara Temple Pond	Non-restored	20,936.8	37.73
Ponniaman Koil Kulam	Non-restored	949.69	22.11
Sri Sengamalathayar Tank	Non-restored	102,210.95	27.24

Source: *Satellite imagery (2024); restoration status from* (EFI, 2020) *and local administrative reports.*

3.3. On-site observations

Restored tanks exhibit clear bunds and vegetation along embankments, and community usage for rituals and small-scale irrigation. Non-restored tanks show heavy siltation, reduced percolation and encroachment by informal settlements or dumping. Elevation data suggests potential hydraulic linkage among tanks within similar altitudinal bands, particularly in the Chidambaram cluster.

4. Research Methodology and Outcomes

4.1. Data Sources

The study primarily relies on secondary data, and physical parameters are measured using satellite images for surface area, perimeter and elevation. Secondary data collected from temple records, Environmental Foundation of India reports, and

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published restoration documentation. Comprehensive documentation of Tamil Nadu's wetlands, including temple tanks, remains limited, as highlighted in regional bibliographic surveys (Balakrishanan et al., 2017).

4.2. Analytical Parameters

For comparative assessment, a set of analytical parameters is considered that deal with the depth, volume, recharge potential and flood detention potential of the temple tanks. The average depth of the tanks is assumed to be 3-4 metres in restored tanks and 2-3 metres in non-restored tanks. The storage volume is calculated using the basic mathematical formula: *Area* × *Depth.* Approximately 10-15% of the storage. Volume per season is thought to be the groundwater recharge potential, while 20% of the monsoon volume is regarded as the flood detention potential. The study also evaluates three prominent comparative parameters —hydrological performance, ecological regeneration, and cultural engagement — to understand how temple tanks contribute to environmental sustainability and sociocultural resilience.

4.3. Quantitative Assessment

The calculated storage volumes and restoration outcomes highlight the difference in hydrological performance between restored and non-restored temple tanks in Cuddalore. While the non-restored tanks possess significantly larger physical capacities, their performance is limited by siltation, poor channels and connectivity and due to a lack of maintenance. Restored tanks, although small in size, demonstrate an improved functionality with constant water retention and great recharge efficiency due to desilting and revived feeders. A pre- and post-restoration comparison shows an increase in the groundwater levels and an improved biodiversity which subsequently results in an enhanced use of the space by the community, thereby reinforcing ecological and social values to the restoration interventions.

Table 2. Calculated Storage Volumes

Tank Name	Average Depth	Volume (m^3)
Padaleeswarar	3	2,113
Sivagangai	4	17,180
Ilamaiyakkinar Koil	4	31,567
Vishveshwara Temple Pond	3	62,810
Ponniaman Koil Kulam	2.5	2,374
Sri Sengamalathayar Tank	4	408,844

Source: *Storage volumes derived from* ***Table 1*** *(Area x assumed average depth, see Section 4.2).*

Data from **Table 2**, taken using satellite images, help form the baseline for assessing the hydrological efficiency and storage performance of each tank category.

Note: *Indicative values adapted from* (EFI, 2020) *and comparable restored-tank*

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outcomes reported for the Chidambaram/EFI initiative, used as a proxy in the absence of primary on-site monitoring for the six tanks studied; this reflects a broader documentation gap discussed in ***Section 4.1.***

Table 3. Pre- and Post-Comparison of Restored Tanks

Indicator	Before Restoration	After Restoration (avg. 2 years)
Avg. Water Level (m)	0.8-1.2	2.4-3.0
Groundwater Table (m)	18-20	10-12
Biodiversity Index/Species Count	12	38
Daily Footfall (average)	35-40	100-150
Local Surface Temperature (°C reduction)	-	1.2-1.8 lower
Ritual/Community Events annually	3-5	7-10

The data in **Table 3** represents the physical and ecological outcomes of restoration across the tanks.

A comparative study of the restoration of the temple tanks, namely Padaleeswarar Tank, Sivagangai Tank and Ilamaiyakkinar Tank, revealed improvements in the hydrological and ecological spheres where groundwater rose by 0.8m to 1.2m within two years, correlating to a 15-20% increase in the recharge rates of the household wells. Tanks, once dry, now retain the water for more than eight months annually, supporting the return of aquatic vegetation and promoting an increase in biodiversity in and around the area. Improved water quality and accessible surroundings have led to an increase of around 30% in the community footfall during rituals and temple festivities, transforming the temple tanks into vibrant socio-ecological spaces, affirming that the restoration not only enhanced the hydrological efficiency of the tanks but also revived the cultural and ecological life of the neighbourhood.

4.4. Observations

Table 3 data shows that restored tanks, although smaller, retain and recharge water more efficiently. This is due to desilting, bund strengthening and properly maintained regulations of inlet and outlet channels. Non-restored tanks possess larger sizes with much greater capacity, but underperform due to siltation and encroachment, thereby reducing their hydrological and social functions.

The restored temple tanks demonstrate a recharge potential of 6,103 m^3, whereas non-restored tanks exhibited a higher potential of 56,883 m^3. The higher potential in non-restored tanks was due to unregulated runoff and unaccumulated silt. Restored tanks show a flood detention potential of 10,172 m^3, whereas the non-restored tanks in the district exhibit around 94,806 m^3, underlining the hydrological capacity of neglected tanks when restored effectively.

A regrowth of vegetation and an increase in the biodiversity index are observed in the restored tanks. Post restoration, an increase in the community footfall is also noticed, as mentioned in **Table 3**, which reactivated the social and spiritual role of temple tanks, strengthening their maintenance through cultural values.

5. Integrated Assessment and Implications

5.1. Hydrological Performance

On comparison to non-restored tanks, restored tanks exhibit effective water retention and recharge rates that are 2-3 times greater. Summer scarcity of water is thereby reduced due to increased groundwater levels by enhanced infiltration and decreased runoff.

5.2. Ecological Role and Living Biodiversity

Restored tanks host three times as many fish, birds and amphibians and the reintroduction of native species in the surroundings and pollution reduction have led to an increase in the aquatic biodiversity of the tanks. This increase in ecology and biodiversity helps maintain a cooler microclimate in the settlement and an increase in shaded area, promoting urban resilience.

5.3. Social and Cultural Framework

Restoration of tanks has renewed ritual practices and increased daily use and community footfall (3 to 4 × rise) and has reactivated public life in and around these tanks. The surrounding neighbourhoods benefit from improved aesthetics, cooler air and informal economic opportunities.

5.4. Policy and Planning Implications

Restoration should focus on larger, high-impact tanks currently not in use. The integration of urban stormwater plans along with aquifer recharge plans can help strengthen and achieve social and hydrological goals.

EFI's Chidambaram restorations (EFI, 2020) validate that community engagement, ecological planting, and consistent desilting could yield both hydrological and social dividends and revive the tank network as multifunctional sacred and climate-resilient infrastructure. Integration of traditional water management and treatment methods can help offer a pathway for sustainable water management which gets rooted in local history and culture (Ogwu et al., 2015).

A notable project is the Mission Kakatiya program in Telangana (Government of Telangana, 2015) which shows a successful collaboration between government and community, retrieving thousands of tanks, and adapting such similar models in the region or in the state of Tamil Nadu could increase restoration outcomes.

6. Conclusion and Way Forward

Cuddalore's temple tanks represent a living tradition that combines community involvement with spiritual symbolism and hydrological function (Amirthalingam, 2009; Chakrabarti & Amirthalingam, 2020). This study establishes that restored temple tanks in the district significantly outperform non-restored tanks across ecological, hydrological and social parameters. Restored tanks demonstrate measurable improvements in performance despite their smaller capacity. An improvement in the

local microclimate is observed along with a rise in groundwater and an increase in biodiversity, thereby showing how temple tanks have revived cultural engagement and re-established their role as a sacred and a civic space in an urban fabric while also serving as a living infrastructure for flood mitigation, aquifer recharge and climate adaptation.

6.1. Recommendations

The need to revitalise ancient methods as workable solutions for water sustainability is reflected in their conservation (Jain et al., 2024; Karuppaiya et al., 2025; Verma et al., 2025) and according to regional research, incorporation of these ancient water systems into modern planning promotes ecological balance, cultural continuity and resilience (Bimrah & Saizen, 2025; Gunasena & Nianthi, 2024).

To strengthen the outcomes, future efforts for restoration should prioritise large capacity tanks, which are majorly underutilised and possess greater hydrological potential. Reviving these temple tanks as urban flood management frameworks can transform them into water reservoirs and recharge hubs, and establishing aquifer monitoring systems would enable long-term tracking of groundwater recharge and hydrological performance, thereby ensuring that the outcomes of restoration are sustainable in water management. Restoration initiatives such as Chidambaram's EFI-led community project (EFI, 2020) and Mission Kakatiya (Government of Telangana, 2015) encourage public-private partnership and demonstrate how the community can help achieve longer-lasting cultural and ecological revival goals.

6.2. Future Scope

This research offers a preliminary hydrological and comparative framework using secondary data, and in order to refine this analysis, further studies should incorporate on-site detailed ecological documentation and surveys. To understand the community perception of the restoration and the sentimental, religious significance of the temple tanks, stakeholder engagement surveys are essential. Expanding datasets and analysing more non-restored water systems in the region could provide a clearer image of the benefits of restoration of these heritage water-based structures in the monsoon season, benefiting the process of flood mitigation and groundwater recharge. This research highlights the need for proper documentation of the temple tanks and the revival of sacred water management systems to support the hydrological, ecological, and socio-cultural revival of the region's culture.

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Sustainable Lessons from the Past: A Study of Rainwater Harvesting Practices at Kanheri Caves

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Abstract: Traditional knowledge and local practices are time-tested systems developed by communities through generations of close interaction with their environment. Based on their understanding of climate and geography, these communities, including Hindus, Buddhists, Jains, etc, lived in harmony with nature. This understanding helped them develop practices that included architecture, agriculture, water conservation, and resource management all rooted in sustainability and community participation. These practices included the indigenous methods to conserve, store, and distribute natural resources efficiently. The paper attempts to analyse the ancient traditional water and land management system in the dynamic metropolitan city of Mumbai that stands as a unique example of a city where ancient heritage and modern urbanism coexist. The city's landscape, formed of basaltic hills and coastal plains, preserves remains of ancient Buddhist rock-cut caves. The purpose of this study is to document and evaluate the current state of the traditional land and water management systems, including tanks, channels, and cisterns, at selected Mumbai cave sites. The study focuses on understanding the effectiveness and seasonal operation of these systems as well as investigating their possible usage for year-round community benefits like environmental resilience and sustainable water practices. Empirical field observations, visual documentation, condition evaluation, and a review of current literature, research papers, and historical records are all part of the methodology. The study aims to demonstrate how old systems are still functional today by contrasting them with current circumstances.

Keywords: Water Management; Rainwater Harvesting; Rock-Cut Caves; Sustainable Practices; Land Management; Conservation Strategies

1. Introduction

For centuries, communities in India developed traditional systems that helped them live in harmony with nature. These knowledge systems evolved over thousands of years and covered diverse fields such as science, engineering, architecture, mathematics, and the arts.

Rooted in daily experience, religious beliefs, and an understanding of local geography and climate, they offered practical ways to simplify and sustain everyday life.
In Buddhism, nature is explained through the Four Great Elements—Earth, Water, Fire, and Air—along with a fifth, Space. These ideas, along with monastic traditions, influenced the development of Buddhist cave architecture across the Indian subcontinent. The caves served as monasteries and meditation spaces, featuring structures such as mandapas, viharas, and chaityagrihas. To give monks shelter during the rainy season, Buddha introduced the practice of *Varsha-Vasa*, which required them to stay in one place and avoid seeking alms. This tradition led to the creation of rock-cut caves as temporary monastic dwellings. [1] (*A study of hydro resource management at early historic site of kanheri, maharashtra: an engineering perspective.* Joshi, R., deccan college postgraduation & research institute, india)

During Emperor Ashoka's reign, Buddhist monks carried the scriptures across the country to spread the Dhamma. Mahadharmarakshita was sent to the Deccan Plateau, in present-day Maharashtra, although Buddhism had already reached the region earlier. [2] (Dr. Qureshi, D. 2010. *Rock Cut Temples of Western India*, C.P. Guatam, Bharatiya Kala Prakashan, Delhi, First Edition: P. 6)

Much of Maharashtra is covered by the basaltic Deccan Traps, a rock well-suited for excavation due to its uniform texture and durability. Basalt is soft enough to carve yet strong enough to endure over time. Ancient builders understood its geological qualities and worked around natural flaws. This made the Deccan Traps an ideal material for Buddhists to create long-lasting rock-cut monuments.

Several ancient Buddhist cave sites—such as Kanheri, Jogeshwari, Mandapeshwar, and the lesser-known Kondivite (Mahakali) Caves—survive in and around Mumbai, preserving the city's historical, religious, and architectural heritage. These sites reveal how traditional knowledge shaped the region's cultural and urban landscape. This paper focuses on the Kanheri rock-cut cave complex and examines how its inhabitants used space for living and developed sustainable water and land management practices. By tracing these ancient systems, the study highlights their relevance today and shows how traditional knowledge offers valuable models for contemporary sustainable practices.

2. About Kanheri Caves

Kanheri, located in Sanjay Gandhi National Park, Borivali, is one of Mumbai's major rock-cut cave complexes. According to ancient Prakrit inscriptions and as mentioned on an ASI board at the site; Kanheri Known as Krishnagiri or Kanhagiri meaning "Black Mountain" the name reflects the dark basaltic hill on which it is carved. The site contains over 110 Buddhist caves, including chaityas, viharas, stupas, and cells, dating from the 2nd century CE to the 11th century CE.[3] (*A study of hydro resource management at early historic site of kanheri, maharashtra: an engineering perspective.* Joshi, R., deccan college post graduation & research institute, india)

Kanheri served as a major Buddhist monastic center where monks lived, meditated, and taught. The site is also notable for its highly efficient water management system, used for over a thousand years, reflecting the great importance placed on water. The ancient monks must have valued water just as much as they do now. The caves are spread across the southern, northern, and eastern hills, with a stream flowing between the southern and northern ranges. Most caves on both hills are oriented toward this stream—northern hill caves facing south and southern hill caves facing north. [4] (*A study of hydro resource management at early historic site of kanheri, maharashtra: an engineering perspective.* Joshi, R., deccan college post-graduation & research institute, india)

Kanheri is well known for its effective water management system. Located in a region with moderate to heavy rainfall, the caves relied entirely on rainwater, which formed streams and waterfalls during the monsoon. With no other natural water sources on the hills, ancient architects designed an efficient system to collect, store, and manage rainwater for use during dry periods, ensuring a reliable supply for the monastic community.



Source - Author Site map of Kanheri Caves

2.1 Water Management System in Kanheri Caves

The main source of water at Kanheri was rainwater, as the area receives moderate to heavy rainfall. The entire hills were transformed into water management systems by ancient architects. During the monsoon season, rainwater flows down the hill, creating small streams and waterfalls near the caves. Since there were no other natural water sources on the Kanheri hills, the monks built a smart system to collect, store, and use rainwater during dry periods. There is a construction that looked like a dam or large reservoir at the intersection of the northern and southern mountains (Figure 0).

The dam wall is estimated to be 4000 mm high and 2400–2500 mm wide. The building of two parallel stone walls facing east and west is responsible for this dam-like

structure's success. The other two sides of the reservoir were naturally accessible as two basalt mountains.



Figure 1.
***Source** – Author Dam Wall 1*

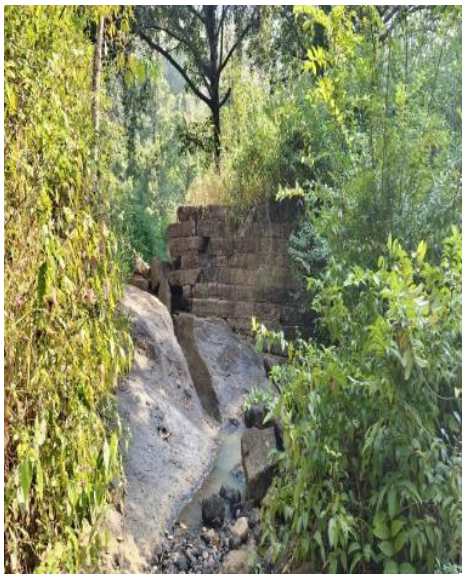


Figure 2.
***Source** – Author / Dam wall 2 with the carved channel*



Figure 3.
***Source** – Author / Rubble coarse Masonary*

To reduce the water flow, a siltation trap was carved into the waterfall's mainstream. As a result, the water is purified from fine particles of sand, clay, silt, and fine particles of dirt. This shows that even though the site is in a region with plenty of rainfall, managing water was still important.





Figure 4 and Figure 5.
Source *– Author /* Siltation trap was carved into the waterfall's main stem outside the cave no 11

They developed a well-designed and sustainable water conservation system, which makes the Kanheri Caves famous for their advanced approach to water management. Evidence of a water harvesting system has been found in Kanheri. Watersprings and rainfall storage are the main sources of drinkable water in basaltic hills like Kanheri.

At Kanheri, rainwater has been kept in cisterns and tanks. There are cisterns in the majority of the site's caves. Nowadays, only few of these have a natural water source in the form of water springs. These cisterns are referred to as "live cisterns" locally.







Figure 6 and Figure 7.
Source *– Author /* Cave 28 Water tank was filled with stream water through the carved channel

Figure 8. ***Source*** *– Author /* Water Tank Connected with the channel

Rainwater harvesting is demonstrated by the existence of tanks and cisterns. Large tanks, small and large rectangular cisterns, small circular cisterns, dams or reservoirs, and water channels are some of the categories into which the water storage elements are identified. The majority of the tanks have a water route that is carved out of the rock and leads to the tank. This is an example of the water waste removal system.

The caves are filled with several carved water cisterns. In order to conserve rainfall, water cisterns, storage tanks, were carved into the solid basalt rock inside

the cave complex. Because these cisterns were usually located at higher elevations, they were gravity-fed and provided easy access to water that had been stored. An early example of sustainable water management was the use of these cisterns to collect and store seasonal rainfall for usage throughout the year. Water management was not only a practical necessity but also had spiritual value, as evidenced by the use of water in rituals such as cleanses and purifications. The monks were able to carry out daily rites, drink, bathe, and even waters any plants within the monastic complex due to the sustainable use of water through cisterns. Every drop of rain that fell on the hills was attempted to be used by ancient hydraulic engineers. There are 4 water tanks at the top as mentioned on the Kanheri cave map. Rainwater storage is the primary use of the tank **Figure 8**. A network of tiny channels connects the majority of the site's tanks and cisterns to one another.

2.3 Land Management System at Kanheri Cave

Architecturally, the Western Indian Buddhist cave complexes consist primarily of two architectural forms developed by the Buddhists - the chaityas (temples) and the viharas(monasteries). These forms became widespread across the Deccan region, and their different stages of evolution can be traced through numerous cave sites scattered throughout western India. Although Kanheri was originally established as a religious and educational center, it gradually developed into a significant commercial hub. Its strategic location along the ancient trade route connecting Kalyan and Sopara made it an important halt for caravans and travellers, which brought increased patronage and contributed to the site’s growth and prominence.

The Kanheri Caves, extending across three hills, were excavated perpendicularly into the slopes a technique that reveals a deep understanding of the terrain and its geological stability. The surrounding landscape included terraced settlements and smaller satellite habitations, suggesting that land use extended beyond the main monastic complex to sustain a wider community and support resource management. The arrangement of water tanks at higher elevations, linked by channels and rock-cut steps, demonstrates a thoughtful approach to land planning that made effective use of the basaltic hills of the Deccan Plateau for both functional and sustainable purposes. A rare feature in one of the caves is a ceiling painting of the Buddha, now largely worn away. It is the only known painting in the entire Kanheri cave group.



Figure 9.
Source *– Author /* Painting on ceiling in cave 34

The caves are interconnected by rock-cut steps and pathways, with channels running alongside to efficiently direct rainwater. The monks also employed a technique similar to drip moulding, designed to prevent water from seeping into the caves.



Figure 10. ***Source*** *– Author /* Drip moulding at cave no 1

These mouldings were positioned in such a way that the water would drip directly into, or close to, the cisterns. A particularly clever system appears near many caves, where the cisterns have narrow channels specifically designed to direct rainwater into them for collection. A wall-cut channel guides rainwater straight into the cistern. Several wall and ground channels around these cisterns further show how thoughtfully the entire rainwater harvesting system was planned across the site.

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Figure 11. and 12
Source *– Author /* wall Chanel connected to the cistern

In the main water stream, several siltation traps carved into the rock functioned as natural filtration systems, allowing sand, clay, and silt particles to settle before the water reached the final cistern ensuring a clean and potable supply for the monastic community.





Figure 13. and 14
Source *– Author / Cave no. 2*

Additionally, a series of small cavities carved in a linear pattern along the vertical surface of the water stream suggests the presence of steps, possibly used to access the stream and collect water when needed.



Figure 15. ***Source*** *– Author /* step to access the water

2.3 Comparative Analysis of Kanheri with Kondivite

Although not as famous as Kanheri, the Kondivite (Mahakali) Caves show similar systems of land and water management, many of which still work today. Both sites are located on the Deccan Plateau, where the basalt rock made it easier for monks to carve strong, long-lasting caves.

Earlier Buddhist caves in India were usually cut parallel to the rock face, but the Kondivite caves marked an important change. Here, the caves were carved perpendicular to the rock surface, allowing more light and air to enter the spaces. This shift was possible because basalt is uniform and easy to carve while still being strong enough to last. This idea was later used at Kanheri too. Unlike Kanheri, Kondivite does not have large open water tanks. Instead, each cave has its own cistern, and many of these are connected underground. These cisterns can be accessed through separate openings, most of which are now covered with metal grills. Like Kanheri, narrow channels carved on the ground and along the walls guide rainwater directly into the cisterns.

The chaitya at Kondivite has a stupa placed inside a circular shrine. The inside walls of this shrine have wide grooves that start from the top and slope down on both sides.

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Figure 16, 17. ***Source*** *– Author / At Kondivite caves*

At the bottom, small holes connect these grooves to a drainage channel that runs around the base of the shrine This channel then carries the water through the hall and out to a cistern placed outside the cave.



Figure 18, 19. ***Source*** *– Author / At Kondivite caves*

There is a natural spring with a small, man-made bowl-shaped basin (Figure 0). This basin allowed heavier particles to settle before cleaner water flowed through a vertical channel into the main cistern outside the cave. A similar system can be seen at Kanheri, showing how both sites used practical methods suited to their landscape.

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Figure 20, 21. ***Source*** *– Author / At Kondivite caves*
Source *– Author / water tank inside the niche at Kondivite caves*



Figure 22. ***Source*** *– Author / Water Tank inside the niche at Kondivite caves*

3. Conclusion

Buddhist monks lived in the Kanheri Caves, and self-sufficiency was a fundamental aspect of their lifestyle. Effective water management became a crucial part of their everyday routine due to a shortage of external resources. Indian society has always placed a high value

on careful water management. The analysis of these caves shows how ancient cultural traditions were conveyed, preserved, and incorporated into civic, religious, and artistic life. We could assume that the ancient inhabitants of Kanheri Caves recognized water and land as the essence of life, as evidenced by their water system, which shows the evolution of monastic structures. The water system at Kanheri Caves transformed from a seasonal water source to a year-round valuable resource, with the use of a rock-cut tank, cisterns, and channels and it has been conserved for the entire year. The structure of rock-cut cisterns demonstrates the advanced engineering skills of ancient India, whose engineers made effective use of natural resources, landscape and surroundings.

This indicates the utilization of the available material of the site. An important part of the practice is the careful design of water storage systems, which shows a mastery of water management and seasonal rainfall patterns. The major Chaitya Griha, stone-carved stupas, Vihara, and developed water management system are all key pieces of physical evidence of a notable interaction between humans and the environment.

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Commoning of Urban Land: Negotiating Space in Case of Jogeshwari-East, Mumbai

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Abstract: Mumbai being the financial capital of India, demonstrates several types of complex land relations. Having emerged gradually over time, these relations are seen to be unique to the corresponding spatial and legal conditions that prevailed at different times. Through the various relations that emerged, the paper intends to discuss the social networks and legal frameworks that facilitated commoning of urban land through the case of the suburb of Jogeshwari-East in the financial capital. The suburb in discussion is spatially significant as it was historically situated just beyond the city limits and politically significant as it came up at the time of the Independence movement. The suburb grew organically on land that was contested to be privately owned by a land administrator belonging to Parsee community while the development that followed had groups of other communities settling and helping people settle based on the provisions of the city administration's ordinances. The post-independence legal amendments are seen to have had severe repercussions on ground creating layers of complexities in ownerships in the process of commoning of land. Therefore, on one hand the laws were readily accepted with a positive change on ground while on the other there were certain incidents of mob violence and riots among stakeholders. This paper is intended to trace the history of spatial development of the suburb and commoning that took place in the process of its development.

Key words: History, land relations, ownerships, rights, commoning

1.Introduction

Mumbai being the financial capital of India demonstrates contestation over every square inch of space. Having grown gradually over time, diverse conditions are seen at its fringes which eventually came to be absorbed within the fold of the city administration. This paper intends to discuss through a thorough primary study of people's history corroborated by archival newspaper articles, the built-form that emerged in the contestation between private property and resultant commoning.

As a welfare state, several measures were taken following Independence to ensure redistribution of land to the people by abolishing the rights of the intermediaries between the people and the state. The case in discussion is a suburb that developed around an important archeological site namely the Jogeshwari Caves, identified as an ASI site in 1958 just beyond the city limits that ended till Andheri in the western suburb. The case under reference, Jogeshwari-East is a suburb covering an area of approximately 210 hectares over four revenue villages namely Ismalia and parts of

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Bandivali, Majas and Mogra. Early town planning efforts in this suburb are seen in the 1920s at two distinct locations within the suburb; one along the railway line sub-station and the other around the caves. The railway substation, the caves and the city limits till Andheri therefore became the catalysts in later development of the rest of the suburb as a predominantly residential suburb comprising of both formal and informal housing.
The three broad claimants to the built fabric in the suburb are the successors of Byramjee Jeejeebhoy hailing from the Parsee community as 'estate holders' (Byramjee Jeejeebhoy(P) Ltd vs State of Maharashtra, 1963), the 'landlords' (Clashes again in Majaswadi, 1964) predominantly coming from Marathi and Hindi speaking communities and the tenants forming a homogenous mix of migrants coming from various linguistic communities from across the country. Being a residential landscape of *kachha and pucca baithi chawls* of different types and sizes, the residences kept being notified and denotified as slums over the period of their existence. The basic elements of the contestation therefore are the ownership of land, ownership of the chawl and ownership of the individual units in the chawl. Despite the contention we can see urban land gradually transforming into commons over the years to a stage where people formed co-operatives to negotiate space in the redevelopment process.

2.Background of the informal housing in the suburb

The suburb has occasionally been in the news for communal tensions ever since it came to be at the limits of the city for nearly seven years between 1951 and 1957 (Extending Bombay City Limits, 1948). It predominantly comprised of rice paddies, cattle sheds, brick kilns and small-scale industries other than formal and informal residences. However, the suburb saw a major shift in land use to cater to the sudden demand for housing the migrants between Independence and the formation of State of Maharashtra in 1960. The village of Majas particularly saw sudden influx of people and growth of informal housing in the form of baithi chawls made using bales, hay, bamboo, cow dung and mud. These baithi chawls imitated the chawls constructed in brick and mortar as both the building materials like cement were sold only upon furnishing approved plans at the rationing store. The initial stance of the central government towards all the informal housing that came up in the city in the 1940s and 1950s was to evict the migrants and demolish the housing units until the formation of the State of Maharashtra when the idea of tolerating the informal housing was brought to force and no further evictions or demolitions took place.

3. The socio-political conditions leading to spatial development:

***The government initiatives*:** The city of Mumbai saw several initiatives undertaken by the government to support the influx of people migrating in search of better job opportunities. The Bombay Housing Board (BHB) that was established to cater to the growing needs of people in the city was responsible for the construction of subsidized housing for the migrants. However, the rate of urbanization was such

that the government couldn't meet the demand as it lacked both capital and land as it was contested vigorously in the courts. And on the other hand, after the establishment of the Bombay Housing Board in 1949, the government undertook construction of houses for the migrants on subsidized values at a payment of nominal amount of Rs. 300, Rs.450 and Rs.600 respectively, based on the size of the housing unit. The migrants had to then apply for subsidized housing with the housing board and wait for their turn to buy a subsidized house. The typologies of houses thus developed cover a range of typologies from *baithi chawls*, *patra chawls*[1], *half patra chawls* and hutments. These typologies were a version of the preceding typology of chawls imitating the housing provided by the housing board. Though the development of *baithi chawls* in this part of the suburb can be traced back to the early 40s it was only in the mid-60s that the patra chawls spread rapidly across the suburb when land was sold in various forms of tenures, most of which were in the form of tenancies. These patra chawls initially formed a stock of transit housing for the migrants. Since it lacked certain basic amenities at the time of construction and spread over vast stretches of land parcels several initiatives were taken to provide for the basic services to the tenements.

This spread of development was challenged time and again in the court of law as 'encroachments' by the state and the superior holders or the heirs of the *Parsee*[2] philanthropist named 'Byramjee Jeejeebhoy' who created 'private trust' to assume the title and ownership of the land as being the original owner of the land according to a 'kowl' of the year 1830 which transferred seven villages to Esq. Cowasji Banaji to carry out development works and collect revenue from the native occupants of the land (Byramjee Jeejeebhoy(P) Ltd vs State of Maharashtra, 1963). Point to note at this juncture is that, it is just a percentage of spread of the area that runs in hundreds of hectares.

On the other hand, the State took initiatives to abolish rights of intermediaries across the country. Several acts were passed like the Khoti abolition act, the Inami grants abolition act, the Salsette Estates act and several others to replace the feudal system of land tenure with State facilitated housing tenure. However, upon the passing of the Salsette Estates (Land Revenue Abolition and Exemption Act) the heirs of Byramjee Jeejeebhoy challenged the act (Validity of Salsette Estate Act Challenged, 1953) stating that the villages in Salsette were to be seen as property purchased from the East India Company. Also, despite the changes in land use and inhabitation by people in the semi-formal manner, in may cases the title of the land

[1] *Baithi Chawls:* The earliest housing typologies in the suburbs, derivatives of the chawls of city built for Mill Workers. *Patra Chawls* are derivatives of baithi chawls commonly built either in bamboo or other sheets

[2] *Parsee*: A religious community originally from Iran having lived in India since 1400s having their base in Sanjaan.

continued to be held by the heirs of Byramjee Jeejeebhoy as per the property registration card.

3.1 The informal/bottom-up initiatives:

As the suburb of Jogeshwari was right at the edge of the city limits large number of migrants who couldn't find shelter in the city lived meagerly at the peripheries. The landscape historically constituted rice paddies, vegetable farms, mango and guava estates with brick kilns and other manufacturing units until the 1930s. Later came other privately initiated small scale businesses such as *tableas*[3] or stables of dairy farms. Interestingly, of all the people interviewed during the primary survey spoke of hindi speaking communities migrated to this suburb by foot having walked over hundreds of kilometers with their cattle from Uttar Pradesh to find new opportunities in the city. The family names of most of those who came from this state, for as enterprising stakeholders as they may have been, were Mishra, Dubey, Tiwari, Nemsingh and several others most of whom had some background in the legal profession while some others who reared cattle and contributed to spread of the dairy industry as a pastoral landscape which supported the city on mainland or called the island city. They built cattle sheds and baithi-chawls alike, further attracting hutments as well to spring in the neighbourhood alongside the properties they built. Perhaps seeing the development of the chawls being the need of hour, the marathi speaking or native tillers and kiln owners also saw a promise in building chawls for the migrants and putting it on rent or *pagdee* owing to the unique *pagdee* system that was prevalent in the city.

At the same time, the Bombay Tenancy and Agricultural Lands Act was passed, the significance of which lies in the fact that on this day the land held by the tillers was legally transferred to the tiller. Following the Salsette Estates Act against this background intermediary interests were abolished by the Government by forming a policy to make over 'Land to the tillers' (Land for the Tiller Soon, 1955)in the then Bombay State under section 32 of the Bombay Tenancy and Agricultural Lands Act, 1948 which provided for compulsory transfer of ownership rights of tenanted lands to the tenants led to the enforcement of what eventually came to be known as the 'Tillers' Day'. A complete sale and purchase of land was made possible through this act. The title of landlord was to pass immediately to the tenant on the tiller's day.

But the gap between the passage of the act in 1948 and its enforcement in 1957 led to further confusion amidst the growing housing demands. This confusion could be well understood in case of the *baithi chawls settlement* of Bandrekar Wadi. It is common knowledge among the older residents that a tiller named Bandrekar tilled roughly 3 hectares of land in this part of the suburb till the late 40s. Back then the

[3] *Tabela* is a cattle-shed in Hindi.

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suburbs were governed by the separate Borough Municipalities, of which the suburb of Jogeshwari-East came under the jurisdiction of Andheri Borough. All statutory permissions for undertaking building activities were to be sought from the Municipal office situated at the suburb of Andheri. Between the enforcement of this act and the judgment on the case, names of these tillers were entered in the revenue registers 'c/o. Mr XX', as an occupant of the land under the ownership/perpetual lease of the Land Owner-Administrator, Byramjee Jeejeebhoy and the revenue for land was being paid on behalf of the land owners-administrators. (Author, 2014)

The tiller's name was added in addition to that of the Administrators. And following the provisions of the Tiller Day' of the Bombay Tenancy and Agricultural lands act meant that the tiller had to approach the regional collector for conveyance of the Title as the sole owner of the land. This can be seen as a critical factor that helps in conjecturing reasons why most tillers do not necessarily have their names in place of the earlier title holder. Also, this suggests that the developments could have come about prior to the enactment of the provisions of the Tillers' Day as demonstrated in case like the development of housing in the Bandrekarwadi Cluster. This could mean that the land use had already been changed from being an agricultural land to residential which is a non-agricultural land use and hence the change of title could not take place due to a complex extralegal or informal arrangement worked out between the land tenant and the structure lord tenant and the authorities in constructing the houses.

In both the above cases the title of the land still rests with the Land Owner-Administrator as against the actual occupants of the land as the recorded association between the Land Owner- Administrator and the Tiller was that of a structure lord-tenant to land, of which the tenant is seen to have bypassed the authorities of Land Owner-Administrator. As mentioned in the last paragraph of section 3 that the land got occupied by the migrant cattle-rearing communities who are known to have supported the city by their daily supply of mild and dairy products and thereby made a living while living on the land belonging to the tenant tillers. These very subtenants to the tenant tillers gradually accumulated wealth to further act as developers developing smaller *baithi chawls* to rent out to individual tenements of the chawls to another tier of stakeholders or tenants.

These subtenants are also wrongly referred as landlords in most cases. However, the revenue assessment for both the land as well as the structure was obtained not from the title holder but from the tenants of individual units in the form of rent. So, the tenants of the individual tenements paid a monthly rent to these another tier of stakeholder or sub-tenants who could also be classified as 'structure-lord' as they were only responsible for the construction of the structure, payment of assessment to the government and maintenance of the structures they built while ensuring the necessary amenities to the new tenants to individual housing units. And as far as the property cards or the receipts to the authorities are concerned the payment of the taxes was made on behalf of all these stakeholders.

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4. Commoning for Redevelopment:

The politics of redevelopment originates with the very idea of redeveloping what are identified as 'slum clusters' under the guise of providing formal housing. This, as the study suggests that it might not necessarily be the need of the hour but an economic venture to support the 'real estate' that keeps the idea of 'development' alive. Further, regularization of these informal housing clusters by way of land taxation leads to added complications of ownership, distribution of rights and mitigating the future urban form. The developer is brought in after the formation of the housing co-operative when 51% of the dwellers are willing to participate in the redevelopment process. Ideally, such a process allows people to debate the need of such a development and identify their requirements. But in case of informal housing clusters that stand on privately owned land it has been observed that the land is first sold to the developer and the dwellers are only later intimated about such a transfer or sale of land. In such a case the developer becomes the sole decision maker of the kind of development he can offer, leaving little scope for negotiation. And the fixed redevelopment norms make it all the more complex. Moreover, after the sale and purchase of land, the developer assigns an agent the task to negotiate and convince the members to then attain 51% consent for the commencement of the project. This was seen in case of the Francis wadi cluster, where the developer is known to have got the land transferred in his name for the redevelopment of the housing cluster in the year 2008. During the initial years, there were fewer than 50% of the dwellers interested in the redevelopment. From then till today, only 550 members out of a total of 997 members are known to have shown interest in the redevelopment.

The complexities that the study points at are unique to every agreement that may have taken place between the parties engaging in transactions at all three levels, be it land, the entire structure or the individual tenement with an additional complexity introduced by the socio-economic and legislative realities at the time the agreements may have been signed. With such a complexity, co- exists another reality of the urban community; its cosmopolitan nature, different from their native or the rural counterparts evident in its use of the commonly shared spaces. It is these spaces in which are anchored the future negotiation get threatened in the process of redevelopment. Irrespective of the typologies that emerge, be it the c*hawls*, the condominiums or the organically formed informal settlements, all seem to blur the religious boundaries in an urban setting. This has given rise to a new form of urban communal land to emerge. For example, the cosmopolitan housing co-operatives in the city, once formed, get exclusive rights to the land as a co-operative body and not as individuals.

Therefore, the study puts forth the idea of 'commoning' of land in urban areas as opposed to private ownership by individuals which in the process of redevelopment could empower the urban community to engage in planning and determining the newer forms of commonly shared spaces and amenities through a democratic process as

against one determined by the real estate lobbyists.

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Cultural Landscape of Resilience: Dhondenling Tibetan Settlement, Karnataka

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Abstract: Cultural resilience is most convincingly demonstrated when identity persists under conditions of rupture. It is understood here not as the static preservation of tradition, but as the capacity of a displaced community to sustain identity, meaning, and social practices through adaptive spatial, institutional, and cultural processes. Dhondenling, a Tibetan refugee settlement in Karnataka, India, emerges directly from a history of forced displacement, temporary transit, and state-led resettlement. This paper argues that Tibetan cultural identity in Dhondenling did not merely survive displacement, but was actively reconstituted through planning, land use, and community institutions.

Established between 1975 and 1978 in Kollegal, Karnataka, the Dhondenling Tibetan settlement represents a pivotal moment in the intertwined histories of Tibetan exile and Indian resettlement policy. Initially conceived as a transit camp, its transformation into a permanent settlement was facilitated by the Mysore Resettlement and Development Agency (MYRADA), which oversaw land distribution and the planning of housing clusters. Located in a fertile valley framed by dense forests, the settlement's landscape is punctuated by monasteries, stupas, and community halls that function as spatial and symbolic anchors, reinforcing religious and cultural continuity.

The spatial organisation of 22 villages, structured around agricultural livelihoods, retains the original planning intent and remains a tangible testimony to resettlement processes. Equally significant are cultural practices such as Men-see-khang, opera and music associations, and handicrafts, which demonstrate a dynamic balance between preservation and innovation. Embedded within festivals and everyday communal life, these practices affirm cultural resilience in exile. Today, Dhondenling stands as a cultural landscape of resilience, where planning, environment, and living traditions are inseparably intertwined, offering insights into how displaced communities negotiate continuity and change within new socio-political and ecological contexts.

Keywords: Cultural resilience; Local Practices; Heritage and Identity; Resettlement Planning; Tibetan settlements in India.

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1. Introduction

The concept of cultural landscapes as articulated by UNESCO and expanded within critical heritage studies provides a foundational lens for this paper. Cultural landscapes are understood not merely as physical settings but as living environments shaped by the continuous interaction between people, belief systems, and ecology (Taylor, 2012). Within this framework, landscapes act as repositories of memory, identity, and social

practice, particularly significant for displaced communities seeking continuity in unfamiliar territories.

Cultural resilience theory further informs this analysis by viewing resilience not as static preservation but as an adaptive process involving continuity, innovation, and transformation (Folke, 2006). Within refugee and post-displacement contexts, resilience is expressed through spatial practices, livelihood systems, ritual life, and institutional structures. Cultural landscapes that showcase resilience are therefore spaces where planning, environment, and living traditions are inseparably intertwined. In this paper, cultural resilience is understood as the capacity of a displaced community to sustain identity, meaning, and social practices through adaptive spatial, institutional, and cultural processes.

Tibetan refugee settlements in India have been deliberately planned to sustain cultural autonomy, religious practice, and socio-economic self-sufficiency. This paper situates the Dhondenling Tibetan Settlement within this broader discourse, highlighting how state-led planning and community agency together shape a distinctive cultural landscape. Dhondenling Tibetan Settlement is examined as a representative case of agro-based Tibetan resettlement in South India. The case study approach enables an in-depth understanding of how spatial planning, environmental context, and cultural practices intersect over time.

For more than six decades, the Tibetan refugee community in India, led by the Dalai Lama and the Dharamshala-based government-in-exile, has been described as a successful model of displacement governance and cultural preservation (Dorjee and Rigzin, 2024). Central to this success was deliberate spatial planning of the settlements. Settlements were intentionally designed to reinforce Tibetan identity and minimise cultural assimilation with the host population (Mehra, 2020). Within these planned environments, traditional knowledge systems have been preserved, adapted and embedded into new socio-ecological contexts in ways that support contemporary community needs. Dhondenling, in Karnataka, thus emerges as a representative case of cultural resilience in exile.

Karnataka hosts the largest population of Tibetan refugees in India. In 1961, the Government of Mysuru allocated more than 3,200 acres of forest land for resettlement, enabling the formation of agricultural villages, or agro-based villages, at first in Bylakuppe, followed by other settlements (Dorjee and Rigzin, 2024). The Dhondenling Tibetan settlement, located at Kollegal, lies approximately 181 kilometres from Bengaluru and 107 kilometres from Mysuru. Nestled within a lush valley, the settlement is framed by dense forest to the west and the Biligiri Rangan Hills to the east, forming a continuous visual and ecological backdrop. Villages are interspersed with broad agricultural fields, opening expansive vistas across the landscape. Nearby ecological features, including a safari zone and the Koulihalla Kere Dam, further

contribute to the region's scenic character and continue to shape livelihood practices and cultural rhythms.

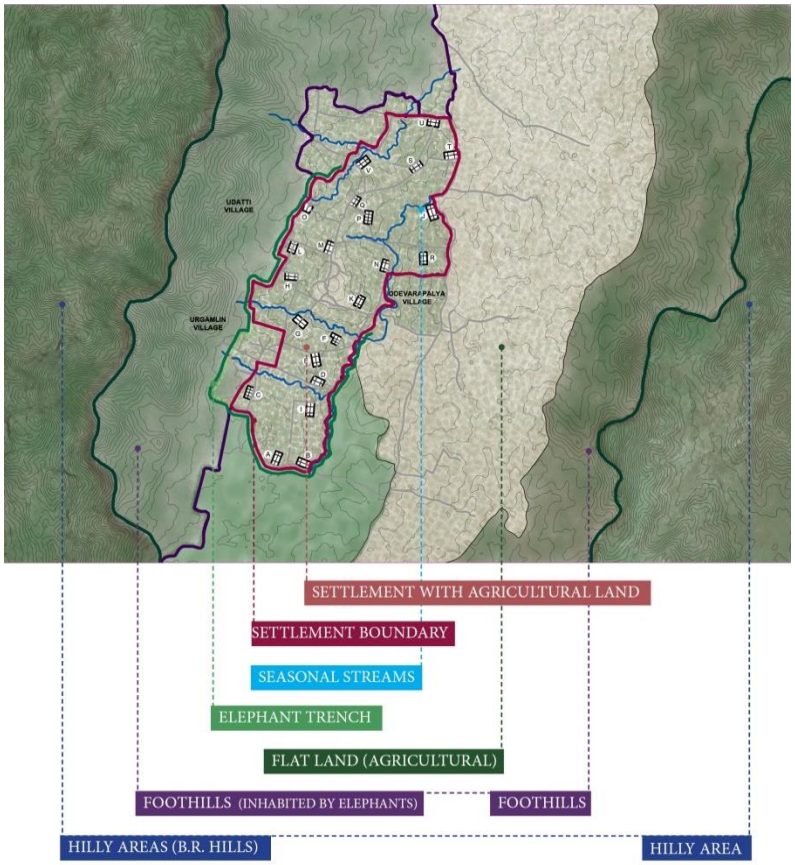


Figure 1. Landscape and layout of villages, Dhondenling. 2024, by author.

2. Historical Context of Displacement and Resettlement

The rehabilitation of the Tibetan community in India following the 1959 exile is widely regarded as a successful resettlement effort, supported by the resolve of India's then Prime Minister, Jawaharlal Nehru (Ahmad, 2012, p.40). With the Dalai Lama's mediation, the Indian government allocated large tracts of uncultivated land across several states. Tibetan refugees, assisted by Indian authorities, were granted approximately one acre of land per person, enabling agricultural self-sufficiency. Bylakuppe, near Mysuru, Karnataka, was the first such settlement established in South India (Michael, 1985, p.741).

In 1960, the Central Tibetan Administration (CTA), a democratic government-in-exile, was founded in Dharamshala (Ahmad, 2012, p.38). Beyond ensuring the basic survival and health of refugees, the CTA prioritized the preservation of Tibetan language, religion, cultural practices, and educational systems to safeguard a distinct identity in exile (Michael, 1985, p.741 and Norbu, 2023). As additional settlements were planned to accommodate the growing community, these objectives shaped both policy and physical design.

Within this broader framework, Dhondenling was established between 1975 and 1978, beginning as a transit camp at Village D. The Mysore Resettlement and Development Agency (MYRADA) subsequently oversaw the transition to a permanent settlement, facilitating land distribution, planning village clusters, and promoting agricultural livelihoods (Central Tibetan Relief Committee, n.d.). Guided by a participatory development philosophy, MYRADA emphasised community-based management, self-reliance, and locally driven decision-making, enabling residents to take active ownership of settlement planning. Its involvement shaped the spatial logic and institutional frameworks that underpin community life in Dhondenling today.

Due to their lack of Indian citizenship for many decades, Tibetans faced legal restrictions: they were ineligible for government employment, required Reserve Bank of India approval to own land or property, and were unable to legally operate companies (Dorjee and Rigzin, 2024). In this context, both the Indian government and the Tibetan exile administration shared a strategic objective, to prevent cultural assimilation and ensure the continuity of Tibetan social institutions. The intentional design of these settlements as culturally autonomous enclaves allowed spatial organisation, community governance, and everyday practices to serve as vehicles of identity preservation.

As these administrative and legal frameworks took shape, the spatial organisation of the settlement emerged as a critical tool for sustaining cultural identity, embedding religious, social, and economic functions within the landscape itself.

3. Settlement Planning and the Cultural Landscape

The Dhondenling settlement comprises a total of 22 villages (A to V) and a central institutional zone. Each village was originally designed with 16 houses, accommodating approximately ten residents per house. Land allocation followed a structured system: each adult was granted one acre of land (40 *guntas*), divided into 8 *guntas* for housing and 32 *guntas* for cultivation, while each child received 20 *guntas*. The settlement spans approximately 3,000 acres, of which 2,535.03 acres remain cultivable. This planning approach reflected the occupational background of many Tibetan refugees, approximately 80 percent were previously farmers or nomads before exile (Michael, 1985, p.741).

Agriculture continues to be the primary livelihood, with 286 active farmers within the settlement. Major crops include maize, potatoes, garlic, *chillies*, and *ragi*, supplemented by vegetables and fruit grown in household kitchen gardens. The land is relatively flat and consists largely of fertile sandy loam and red soil, supporting diverse cultivation.

Topographically, the settlement is situated between the B.R. Hills and forested terrain to the west, with low, undulating hills on the opposite side. A main regional road connecting Bengaluru and Mysuru runs parallel to the eastern boundary, while internal village roads-oriented east–west offer panoramic views of the B.R. Hills. Nearby

attractions such as the Koulihalla Kere Dam and periodic safari routes through forested tracts contribute to the scenic qualities of the landscape and its emerging tourism potential.

Each settlement is administered by a Settlement Officer appointed by the Central Tibetan Administration (CTA). Members serving under this officer are elected by residents. Most Tibetan exiles hold a "green book" or "freedom booklet," which records voluntary contributions to the CTA collected locally by the Settlement Officer (Rathee, 2010, p.8). Separate land parcels, often around two acres per village, are allocated for monasteries, which are self-administered. Five monasteries, located within close proximity, form a tourist loop frequently visited by outsiders within Dhondenling.



Figure 2. The architecture of the monasteries in Dhondenling. 2024, by author

In addition to monastic complexes, community halls, small stupas, and structures housing Mani wheels are strategically positioned throughout the settlement, functioning both as public gathering spaces and visual markers in the landscape. A small number of guesthouses, cafés, general stores, and handicraft shops serve residents and visitors. Culinary practices remain distinctly Tibetan, with cafés offering foods such as *shabalay, tsampa*, and butter tea. A modest market area is located near Village K, supported by several small-scale factories producing local goods within and around the settlement.

At the geographic centre lies the public institutional core, housing facilities such as the Sambhota School, hospital, Men-Tsee-Khang (traditional Tibetan medical clinic), gymnasium, and settlement offices.

Community halls, typically designed in the Tibetan architectural style, are accompanied by stupas and prayer wheels that reinforce cultural presence. Many villages also maintain old-age homes, reflecting community-based care practices.

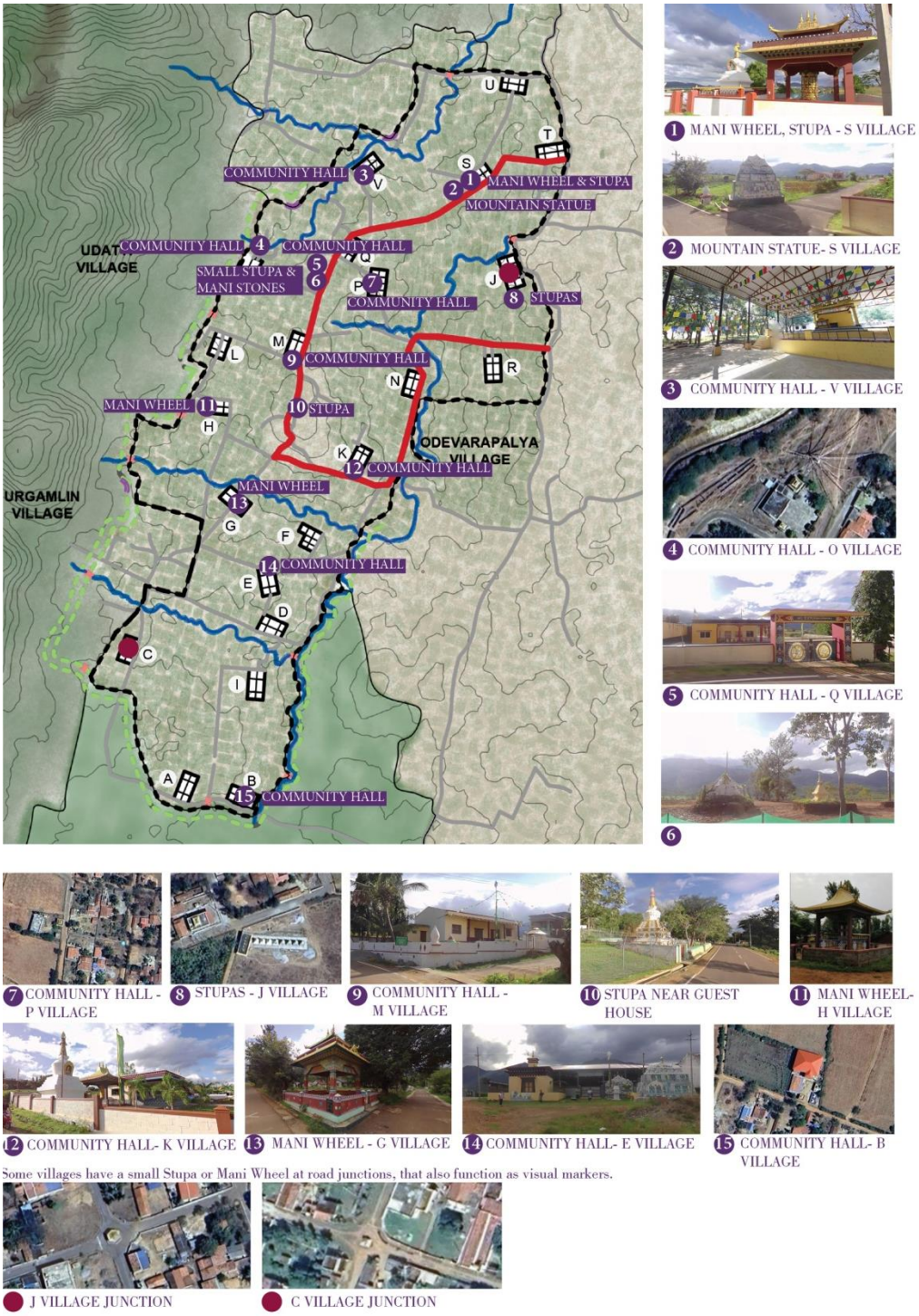


Figure 3. Mani wheels, stupas, community halls within Dhondenling. 2024, by author

The planning logic and spatial design of Dhondenling remains a tangible testament to a pivotal moment in the histories of both the Tibetan diaspora and the Indian state. The land distribution patterns and housing provisions continue to embody the original resettlement intent. Here, landscape is not merely backdrop; it actively shapes practices, beliefs, and identity formation.

4. Traditional Knowledge Systems in Everyday Life

Agriculture remains the primary source of income for the settlement. Farmers cultivate maize, *ragi*, potatoes, ginger, garlic, beans, and chillies, while the Organic Research and Training Centre (ORTC) provides support through training programs, crop diversification initiatives, and the introduction of organic farming methods. Produce is consumed locally and sold to nearby markets in Karnataka and Tamil Nadu, integrating the settlement into regional economic networks.

Education emerged early as a critical mechanism for cultural continuity. The Council for Tibetan Education established nursery schools at Dharamshala, forming what would become the Tibetan Children's Villages (TCVs) (Michael, 1985). Over time, similar institutions were developed across settlements. TCVs promote cultural pedagogy through activities such as bread and noodle-making, language instruction, and volunteer programs with the CTA and Tibetan organisations. Summer programs enable youth to relearn ancestral language, reinforcing linguistic and cultural transmission across generations.

The Men-Tsee-Khang within Dhondenling operates as a small traditional medical clinic offering consultations, herbal medicine, cupping, and cotton therapy. Established originally in Dharamshala in 1961, Men-Tsee-Khang is the premier institution safeguarding Tibetan medical and astrological knowledge, combining diagnostic, therapeutic, and spiritual approaches rooted in Tibetan cosmology. Within Dhondenling, the staff includes a doctor, astrologer, dispenser, an accountant, and cleaner. Treatments follow Tibetan medical epistemologies, which integrate understandings of nature, bodily balance, and spirituality. While modest in scale, the clinic serves as an important locus of intangible heritage and everyday practice. Handicraft traditions such as thangka painting, wood carving, metalwork, and the production of ritual objects continue within the settlement, preserving artisanal skills while supplying monasteries, shops, and occasional tourist demand.

Economic organisation further supports knowledge transmission. Tibetan refugees established a cooperative society in 1961 to facilitate trade in Bylakuppe (Bentz 2012, p.89), a model later adopted across settlements. Milk cooperatives and farmer-led collectives continue to operate fostering communal agency.

Together, these practices demonstrate how livelihood systems, artisanal knowledge, education, and traditional medicine remain deeply embedded within everyday life. Their persistence, in an unfamiliar social and ecological context, illustrates how displaced communities negotiate continuity through adaptive cultural resilience.

Together, the spatial organisation of the settlement, the persistence of agricultural livelihoods, the continued practice of traditional medicine, and the maintenance of artisanal and educational institutions reveal how cultural identity is actively reproduced through everyday life. Rather than functioning as isolated elements, these practices

intersect through community governance, shared spaces and routines, transforming Dhondenling into a cultural landscape where memory and tradition are materially and socially inscribed. In navigating new ecological conditions and socio-political frameworks, the community demonstrates an adaptive resilience, maintaining core values while evolving practices to suit local contexts. The settlement therefore exemplifies how traditional knowledge systems can be sustained, transmitted, and reinterpreted in displacement, offering insight into broader processes of continuity, adaptation, and identity formation in exile.

5. Performing Arts and Intangible Heritage

Performing arts remain a vital conduit for cultural expression and intergenerational learning within Dhondenling. The Opera Association (20–25 members) and the Music Association (18 members) actively engage mixed age groups through daily classes in Tibetan and Western musical traditions. Specialist teachers are periodically invited from the Bylakuppe settlement to strengthen technical proficiency, ensuring that local capacity continues to grow. Performances are staged during major festivals and official visits, maintaining community cohesion and reinforcing shared cultural memory. These groups negotiate a careful balance between sustaining traditional forms and experimenting with contemporary artistic modes. However, limited equipment, storage, and rehearsal spaces continue to challenge long-term sustainability. The Community Hall serves as the primary venue for performances during festivals, daily rituals, and weekly gatherings, reinforcing its role as a social and ritual nucleus.



Figure 4. Costumes used by the Opera Association. 2024, by author

Additionally, sports constitute another important facet of intangible cultural life. Dhondenling hosts an active football program through which youth participate in tournaments such as the Gyalyum Chenmo Memorial Gold Cup, involving Tibetan settlements across India and the diaspora. The South Tournament, connecting

settlements in Karnataka and Goa, and the Trunker Cup, held on the birthday of His Holiness, further embed sports within ritual calendars. Basketball tournaments during Losar amplify the festive dimension of athletic activity.
Visual and material culture, meanwhile, is maintained by a small number of artisans practicing traditional crafts, with only two or three shops selling religious items in silver and brass, reflecting a shrinking pool of practitioners.

Festivals such as the Tibetan Lunar New Year activate collective performance, ritual exchange, and gastronomic traditions. One significant ritual practice, Lhakar or "White Wednesday," designates Wednesdays as auspicious days dedicated to cultural affirmation; community members gather in the community hall, dress traditionally in *chubas*, have group activities like circle dances (*gorshey*), and vendors sell butter tea, and Tibetan food. Lhakar embodies a conscious strategy of cultural preservation through everyday action. Observance often includes wearing traditional attire, speaking Tibetan in public settings, and purchasing locally produced goods, strengthening everyday cultural resistance.



Figure 5. Women wearing the chuba and performing the gorshey in the community hall, Dhondenling. 2024, by author

These festivities also reactivate traditional social practices such as communal dancing, the brewing and sharing of butter tea, and the performance of ritual chants, reinforcing cohesion through repeated embodied traditions.

6. Mechanisms of Knowledge Transmission

Knowledge transmission in Dhondenling occurs through monastic, familial, and community-based pathways. Monastic education remains central: monks who fled during the Tibetan diaspora carried books, ritual objects, and art pieces, enabling the re-establishment of pedagogical lineages within exile. Major Gelukpa institutions such as Sera, Drepung, and Ganden, once the intellectual apex of Tibetan scholasticism, were

re-founded in southern India, providing institutional continuity (Michael, 1985, p.742). Their curricular frameworks continue to shape ethical, philosophical, and ritual knowledge for younger generations.



Figure 6,7. Incesse making and noodle making workshop, Dhondenling. 2024, by author

Alongside monastic instruction, family and community-based learning systems transmit everyday practices, dialects, foodways, and ritual etiquette. Preserving intangible heritage for the third generation of refugees remains a pressing challenge, as cultural memory becomes more distanced from the lived experience of Tibet (Ahmad, 2012, p.40). Ritual calendars, structured around auspicious days, agricultural cycles, and commemorative events, further scaffold embodied knowledge, reinforcing behavioral norms and community cohesion. Traditional ritual practices, etiquette, and oral histories are transmitted through participation in household ceremonies and agricultural seasons, which serve as informal pedagogical spaces for younger generations.

7. Negotiating Continuity and Change

Adaptation has been a defining feature of Tibetan exile life. Economic success and the establishment of a strong democratic governance structure have been positioned as foundational for sustaining Tibetan identity and pursuing long-term political aspirations (Bentz 2012, p.92). While agriculture formed the original livelihood base, urban migration and diversification into tourism, hospitality, workshops, and arts-and-craft enterprises reflect broader shifts. Cultural norms such as wearing the *chuba* when visiting a monastery continue to anchor identity in practice (Rathee, 2010, p.17), even as settlement residents navigate modern educational aspirations, external labour markets, and changing aspirations among youth. Such traditions, spanning dress codes, food preparation, and formal greeting rituals, are consciously maintained as markers of collective identity amidst broader socio-economic transformation.

These dynamics reveal a delicate negotiation: integrating contemporary economic opportunities without destabilizing cultural values. The settlement's cultural

institutions, community halls, prayer flag parks, craft shops, ritual spaces, mediate this shift, recalibrating tradition rather than abandoning it.

8. Cultural Landscape as Repository of Memory

Dhondenling's landscape functions as an archive, embedding memory in spatial form. Built elements and ritualized spaces have been adapted to enable the continuity of Tibetan lifeworld's under new ecological and political conditions. Scholars describe refugee settlements as "Little Tibets" (Bentz, 2012, p.94), intentionally planned to mirror the geographical, social, and religious distribution of the homeland. Such planning replicates core symbolic structures, enabling a socio-spatial continuity that is as psychological, emotional as it is functional.

Community memory plays a formative role: the landscape becomes a vessel for an imagined homeland, a shared orientation toward return (Rathee, 2010, p.15). In this sense, the cultural landscape mediates between displacement and belonging, materializing identity through monasteries, community halls, ritual pathways, and agricultural fields. Traditional practices tied to these spaces, such as installing *mani* wheels, incense-burning, and prayer-flag.

installations, visually inscribe cultural meaning onto the landscape, materializing memory through ritual action.



Figure 8, 9. Prayer flags as makers of visual identity, Dhondenling. 2024, by author

9. Conclusion

Taken together, the performing arts, ritual calendars, monastic learning, and spatial practices of Dhondenling demonstrate a pattern of adaptive continuity, wherein tradition is neither static nor diluted but actively recalibrated to contemporary realities and needs. Dhondenling is therefore read as a dynamic landscape of resilience, where planned settlement forms, agricultural systems, and cultural institutions enable long-

term cultural continuity while responding to new ecological and political conditions. Traditional knowledge systems are reproduced through social participation, embodied performance, and spatial memory, even as economic diversification and youth mobility reshape communal priorities. The settlement's cultural landscape thus operates as both repository and interface, holding memory, and exemplifies the ways displaced communities strategically negotiate continuity and change across shifting socio-political and ecological contexts. Together, these traditions mediate belonging, translating memory into embodied practice and ensuring cultural continuity beyond the homeland.

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Many of the observations presented in this paper draw from direct interactions with community members and on-site examinations of the settlement's landscape and cultural institutions.

Conflicts of Interest:

No external organisations or funding bodies were involved in the preparation of this paper, and all views and interpretations are those of the author. Supplementary statistical information was sourced from the Central Tibetan Administration website and through data provided by local authorities.

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Adaptive Reuse of Maratha-Era Wadas: A Framework for Living Heritage

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Abstract: Heritage buildings that previously had important sociopolitical and cultural functions but are now neglected as a result of growing urbanisation can be found in Indian cities' historic cores. Of these, the traditional Wadas of Pune—residential complexes from the Peshwa era, is extremely important both architecturally and culturally. Its adaptive reuse as a socio-cultural centre that establishes a balance between heritage preservation and contemporary functionality is the subject of this study.

In order to find chances for adaptive changes, the study looks at the wada's spatial organisation, including its courtyards, circulation, and communal areas. While design insertions like exhibition rooms, multipurpose halls, and community gathering areas are suggested for contemporary relevance, key architectural features—stone plinths, timber columns, carved brackets, and pitched roofs—are maintained to preserve historical authenticity.

An important component of our idea is sustainability. Reusing original materials, bringing back passive cooling techniques like verandahs and courtyards, and incorporating eco-friendly improvements all lessen their negative effects on the environment while improving comfort. Additionally, by guaranteeing that the wada stays a living area rather than a static artefact, adaptive reuse promotes cultural continuity.

According to the research, the adaptive reuse of Pune's Wadas as socio-cultural institutions serves as a template for historical education, inclusive community involvement, and regional economic development. It supports resilient urban development by fusing traditional knowledge with modern demands and provides a reproducible framework for renovating comparable heritage buildings throughout India

Keywords: Heritage Architecture; Sustainability; Cultural continuity; Pune Wada; Adaptive reuse

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1. Introduction

1.1 Background

Maharashtra's Wadas, which were primarily created during the Maratha era (17th–19th century), are essential to the state's architectural and culture legacy. They blended household life, administration, and social activity with their central courtyards, timber frames, stone plinths, and carved facades; their thick walls, lime plaster, and courtyard design offered passive thermal comfort (Kulkarni, 2015; Deshpande, 2021).

By prolonging a Wada's life and reviving its cultural significance, adaptive reuse provides a viable substitute for conventional conservation (Kaur & Singh, 2022). By

converting these buildings into museums, cultural institutions, or community centers, Pune's historical character can be preserved while meeting modern urban demands.

In order to guarantee that Wadas continue to be dynamic contributors to contemporary urban life rather than immobile monuments, this study suggests a framework for adaptive reuse throughout Maharashtra that emphasizes cultural continuity, community involvement, and minimal intervention.

1.2 Problem Statement

Despite their historical and architectural significance, traditional wadas are under risk from urbanization, neglect, encroachment, and fragmented ownership. Many privately owned Wadas are left unprotected by heritage rules that favor listed sites (Arora, 2020).

Due to the lack of an integrated framework for adaptive reuse, unrecorded Wadas run the risk of being over restored or abandoned (Patil & Gokhale, 2023). In order to close this gap and turn Wadas into sustainable, culturally rich urban assets, this study suggests a contextual adaptive reuse strategy.

1.3 Aim and Objectives

1.3.1 Aim

To create a paradigm for context-sensitive adaptive reuse of traditional Wadas that incorporates sustainable design principles, community involvement, and cultural conservation.

1.3.2 Objectives

1. To review traditional Wadas' spatial organisation and architecture using visual analysis and documented examples.
2. To study vernacular heritage-related adaptive reuse precedents and principles.
3. To analyse Wadas's functional and sociocultural changes throughout time.
4. To identify the ownership, policy, and material limitations that are obstacles to conservation and reuse.
5. To set out a paradigm for conceptual adaptive reuse that encourages continuity between conventional wisdom and modern demands.

1.4 Scope of Research

The traditional Wadas in West and South Maharashtra, specifically in Pune, Satara, and Kolhapur, are the subject of this study. In order to comprehend their architectural character, cultural significance, and potential for adaptive reuse, representative case studies like Vishram baug Wada, Nana Wada, and Bhosale Wada are examined; in order to create a flexible framework that encourages heritage revitalization through functional and cultural integration, the research looks at spatial organization, material systems, and reuse strategies.

1.5 Limitations

The study uses secondary research and online sources because site access is restricted. Aspects of structural and legal conservation are not included. With the exception of rural examples, the emphasis is still on metropolitan and semi-urban Wadas. The suggested conceptual framework acts as a guide for upcoming legislation and execution. Regions such as North Maharashtra, Marathwada, and Vidarbha are not covered in this study, which may present opportunities for further research.

2. Literature Review

2.1 Maratha Domestic Architecture and the Wada Typology

The social and environmental circumstances of the Maratha period (17th–19th centuries) influenced the evolution of the Wada type. Wadas represented the communal way of life and hierarchical structure of Maratha society by acting as homes, administrative hubs, and social gathering places (Kulkarni, 2015).

Their layout was centred on a central courtyard, or chowk, which served as a common area for gathering and as a source of light and air. Climate adaptation and isolation were improved by surrounding features such verandahs, otla (plinths), and mezanis (balconies) (Deshpande, 2021). Wadas have sloping clay-tiled roofs and timber frameworks supported by brick or basalt masonry. Brackets and facades with intricate carvings showed both structural intelligence and skill (Patil & Gokhale, 2023).

Wadas was a prime example of early sustainable architecture by incorporating rainwater drainage, shaded corridors, and passive ventilation. In order to comprehend this vernacular typology and direct adaptive reuse methods in the present day, surviving specimens such as Vishram baug Wada, Nana Wada, and Bhonsale Wada continue to be essential resources.

2.2 Case Studies of Restored Wadas

Maharashtra is home to a number of adaptive reuse projects that show how traditional Wadas may be effectively recreated in modern settings.

2.2.1 Vishram baug Wada, Pune



Figure 1. Vishram baug Wada © Incredible India

Maratha household architecture is well shown at Vishram baug Wada (1811). The Pune Municipal Corporation restored it as a museum and heritage site, showing real architecture modified for modern usage while maintaining courtyards, wooden facades, and carved columns while using contemporary lighting, displays, and circulation (Kulkarni, 2015).

2.2.2 Nana Wada, Pune



Figure 2. Nana Wada © Hindustan Times

Restored in the late 20th century, Nana Wada functions as both a school and a heritage information center. Community-based initiatives support the repurposed heritage site's cultural continuity, and the project added new service facilities while maintaining its wooden framework and courtyard layout (Deshpande, 2021).

2.2.3 Bhonsale Wada, Kolhapur



Figure 3. Bhonsale Wada © Justdial

For public events and cultural gatherings, a portion of Bhonsale Wada has been modified. While allowing for flexible use for concerts and community events, the restoration places a high priority on structural stability and aesthetic integrity. Its multi-courtyard design exhibits spatial adaptability and can be replicated on a larger scale in comparable buildings (Patil & Gokhale, 2023).

2.4 Learnings from Previous Research

Consistent results from several investigations are revealed by a review of the current literature:

Architectural Consistency: The majority of Wadas include peripheral rooms that adhere to the courtyard typology, demonstrating the standardisation of adaptive reuse techniques.

Condition Disparity: Ownership disputes and ignorance are the main reasons why almost 40% of the Wadas surveyed are still in poor condition (Patil & Gokhale, 2023).

Cultural Disconnection: Wadas are seen as outdated by younger generations, despite their relevance as cultural symbols by older generations. This highlights the necessity for interesting reuse models (Arora, 2020).

Potential for Sustainability: Wadas are perfect for reuse-based conservation because of their material and spatial qualities, which naturally promote passive cooling, natural lighting, and lifespan (Deshpande, 2021).

Policy Gap: Uneven conservation efforts result from Maharashtra's lack of a single policy for privately owned or vernacular cultural monuments (Kaur & Singh, 2022).

3. Research Methodology

The qualitative, exploratory methodology used in this study prioritizes functional, cultural, and architectural factors over technical measurements. The research was guided by a thorough literature analysis on conservation, adaptive reuse, and Maratha domestic architecture. Online case studies three refurbished Wadas—Bhonsale (Kolhapur), Nana (Pune), and Vishram baug (Pune)—were examined to evaluate adaption measures due to restricted accessibility. Important factors including material integrity, cultural integration, and spatial hierarchy were assessed by comparing their architectural and functional changes. A conceptual adaptive reuse framework that outlines architectural principles, zoning tactics, and intervention guidelines appropriate for various Wada situations was created by synthesizing the data.

4. Analysis and Findings

The goal of the analysis is to comprehend the sociocultural aspects, architectural traits, and condition evaluation of traditional Wadas in West and South Maharashtra. In order to understand the heritage value and possibility for adaptive reuse of these structures, this part compiles information from literature, online case studies, and comparative analysis.

4.1 Architectural Characteristics of Maratha Wadas

Wadas are the tangible representation of Maratha-era architecture, showcasing the period's advanced technological and cultural capabilities.

Their architectural style is an integral element of Pune's and Maharashtra's historic fabric, reflecting a thoughtful reaction to climate, community structure, and cultural meaning.

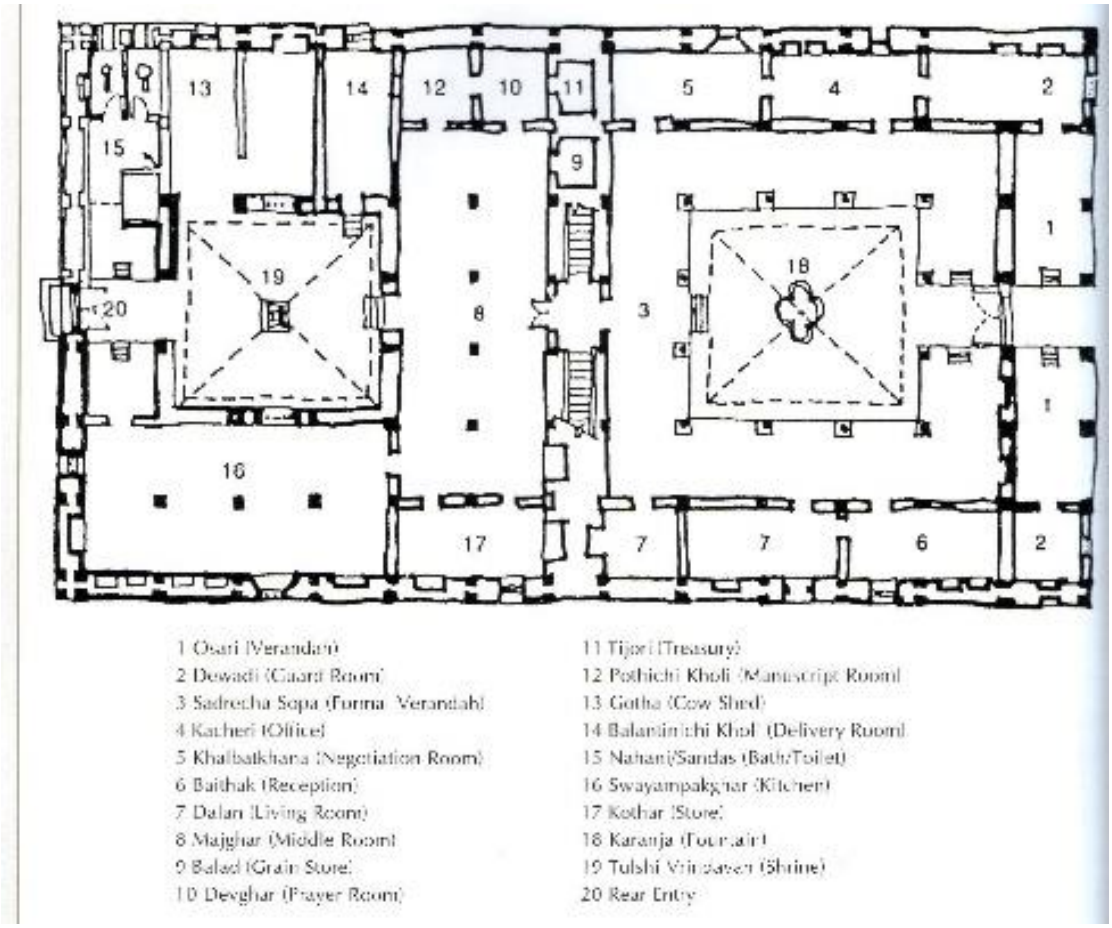


Figure 4. Typical Floor Plan of Wada's (Développement, n.d.)

Feature	Description	Significance
Layout	Central courtyard with peripheral rooms; multiple courtyards in larger Wadas	Climate adaptation, social interaction
Material Use	Stone plinths, timber frameworks, clay tiles, brick masonry	Durability, thermal comfort
Decorative Elements	Wooden carvings, arches, balconies, lattice windows	Reflects cultural aesthetics
Functional Features	Kitchens, storage spaces, administrative halls, secret passages	Social, political, and economic role
Defensive Structures	Heavy doors, fortified walls, inward-facing planning	Security and privacy

Table 4.1: Architectural Characteristics of Maratha Wadas

4.2 Condition Assessment of Wadas

A comparative analysis of Wadas throughout Maharashtra using secondary data and online case studies showed differences in adaptive reuse between privately owned and state-protected monuments, indicating varying degrees of preservation.

Wada Name	Location	Ownership	Current Condition	Conservation Status
Shaniwar Wada	Pune	State-controlled	Ruined but preserved	Monumental remains; partial restoration; public monument
Vishram baug Wada	Pune	Municipal	Fair; partly reused	Converted into museum; adaptive reuse model
Junnar Wada	Junnar	Private	Poor condition	Minimal conservation; at risk of collapse
Patwardhan Wada	Satara	Private/Family	Moderate; inhabited	Informal maintenance; no formal restoration
Bhonsale Wada	Kolhapur	Institutional	Good; maintained	Used for cultural functions; actively preserved

Table 4.2: Condition of Representative Wadas in Maharashtra

4.3 Socio-Cultural Dimensions of Wadas

Wadas have enormous intangible cultural significance in addition to their magnificent architecture. Throughout history, they have acted as administrative, social, and cultural pillars that have influenced urban identity and community life.

Period	Function of Wadas	Community Impact
Maratha Period	Residences and administrative centers of nobility	Seats of power and socio-political authority
Colonial Period	Residences and centers of reform and resistance	Cultural continuity under colonial rule
Post-Independence	Fragmented ownership; occasional social events	Decline in urban social role
Contemporary Era	Heritage attractions; adaptive reuse initiatives emerging	Renewed cultural pride and economic opportunities

Table 4.3: Socio-Cultural Roles of Wadas Across Time

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4.4 Key Findings and Interpretations

Architectural Resilience: Wadas's structural systems, which are made of lime, brick, and timber, exhibit exceptional reusability. Their modular designs allow for a variety of uses without requiring significant changes.

Cultural Continuity: Wadas maintain their symbolic link to Pune's cultural memory in spite of their physical deterioration. Using living heritage models, adaptive reuse could bring this cultural continuity back to life.

Functional Flexibility: Open layouts, verandahs, and courtyards provide a great deal of spatial flexibility, enabling less invasive uses as exhibition rooms, libraries, or cafés.

Conservation Gaps: Disjointed restoration attempts result from a lack of a single historic policy for vernacular architecture. The majority of private Wadas are still not protected by the government.

Possibility of Reuse Framework: To ensure long-term sustainability and public involvement, a city-level adaptive reuse plan for Wadas might incorporate community areas, cultural education, and tourism.

4.5 Stakeholders in Adaptive reuse

Depending on ownership patterns, various stakeholders in Maharashtra engage in adaptive reuse of Wadas. Vishrambaug Wada has been restored and transformed into a museum and public heritage area by government organizations like the Pune Municipal Corporation.

In Bhonsale Wada, Kolhapur, trusts and organizations actively maintain the property for cultural events and public gatherings, demonstrating institutional ownership.

Due to financial limitations and a lack of government assistance, privately owned wadas, like Patwardhan Wada in Satara, are maintained by individual owners, frequently through unofficial repairs.

Although they do not directly own these properties, heritage NGOs like INTACH serve as advisors through documentation, heritage walks, and awareness campaigns.

Ownership determines maintenance responsibility:

- Wadas owned by the government and run by state or local agencies Institutional Wadas are overseen by organisations or trusts.
- Self-funded private wadas owned by individuals
- This emphasize how crucial it is to provide private heritage property owners with financial assistance, policy support, and technical advice in order to guarantee long term conservation.

4.6 Integration with Visual Analysis

Wada spaces may be redesigned without structural changes because to conceptual designs that cover material mapping, adaptive reuse patterns, and verandah interpretation.

- A social link between public and private spaces is provided by the verandah.
- The courtyard, which can be used for performances or cultural exhibits, continues to be the focal point of the space.
- Access points and circulation routes direct guests and encourage narrative in reuse plans.
- When taken as a whole, these examples highlight the possibility of dynamic, inclusive, and participatory preservation as opposed to static.

5. Design Proposal

5.1 Concept Title - "Wadas as Living Heritage: Adaptive Reuse Rebuilds Cultural Memory"

5.2 Concept Statement - The plan reimagines ancient Wadas as Living Heritage Hubs that bring together contemporary urban life with Pune's historic core. It places a strong emphasis on using small, durable, and reversible actions to restore social and cultural life. Each modified Wada is transformed into a self-sustaining cultural venue that embraces modern relevance while maintaining tradition, guided by the Maratha values of craftsmanship, community, and climate response.

5.3 Proposed Zoning and Spatial Use

No.	Existing Spatial Image	Proposed Spatial Image	Description
5.3.1	 **Figure 5.3.1. (a)** Existing Verandah © author	 **Figure 5.3.1. (b)** Wada's Veranda: An Interactive Transitional Area	The refurbished verandah at the Wada's entry serves as a storytelling area for guests and makes a smooth transition between the outside and indoors. Through interactive displays and carefully chosen installations, it links architecture, history, and regional narratives while preserving its original timber columns, tiled roof, and rhythmic arches. Warm lighting improves the authenticity of materials, demonstrating how adaptive reuse can turn conventional components into surroundings that are meaningful and immersive.
5.3.2	 **Figure 5.3.2. (a)** Existing Courtyard © author	 **Figure 5.3.2. (b)** The Wada's Cultural Centre is the expansive central courtyard.	The cultural centre of the Wada is the central courtyard, which hosts performances, art exhibits, and seasonal activities. This open-to-sky area maintains its original spatial hierarchy and serves as a dynamic core that unites tradition and modern expression. Its function as a place of continuity and connection is strengthened by the interaction of natural light and conventional materials.

5.3.3	 **Figure 5.3.3. (a)** Existing Chamber © author	 **Figure 5.3.2. (b)** Galleries of Life — Side Rooms of a History	In this illustration, the Wada's flanking chambers are transformed into thematic galleries displaying Pune's trades, reformist movements, and household life. Restored finishes, carefully chosen exhibits, and sensitive lighting create immersive, narrative spaces that bring the city's history to life while preserving the architecture.
5.3.4	 **Figure 5.3.4. (a)** Existing Chamber © author	 **Figure 5.3.4. (b)** The Transition Zone is the rear wing of a vintage	The back wing of the Living Museum transforms into a narrative bridge that charts Pune's development from Maratha capital to contemporary cultural centre using multimedia and projections. While maintaining the structural integrity of the Wada, technology improves engagement.
5.3.5	 **Figure 5.3.5. (a)** Existing Verandah © author	 **Figure 5.3.5. (b)** Storytelling on Heritage Walls using Projection Mapping	The picture shows projection mapping, which is used to tell tales of Pune's history and craftsmanship straight into the interior surfaces of the Wada. Without modifying the existing structure, this non-invasive adaptable technology transforms walls into canvases for storytelling, fusing media and architecture to produce immersive learning environments.

5.3.6	 **Figure 5.3.6. (a)** Existing Verandah © author	 **Figure 5.3.6. (b)** Conventional Veranda — The Point of Immersion	The entrance verandah, which acts as a transition between the outside and the inside, is shown in this picture. It now serves as an orientation area that tells the Wada's heritage while keeping its timber columns and tiled ceiling. The tone for the internal sensory experience is established by interactive displays and visual exhibitions that establish a cultural threshold.
5.3.7	 **Figure 5.3.7. (a)** Existing Courtyard © author	 **Figure 5.3.7. (b)** Small Outdoor Amphitheatre: The Courtyard Stage	The image displays the courtyard's planned little amphitheatre. The stepped seating, which was designed with little interference, blends in with the ground plane and provides a space for community gatherings, storytelling, and music. While preserving the Wada's historic openness and spatial harmony, the adaptive usage improves social interaction.
5.3.8	 **Figure 5.3.8. (a)** Existing Courtyard © author	 **Figure 5.3.8. (b)** Glowing Light Sculptures in an Art Installation: The Festival of Forms	The image displays the courtyard's planned little amphitheatre. The stepped seating, which was designed with little interference, blends in with the ground plane and provides a space for community gatherings, storytelling, and music. While preserving the Wada's historic openness and spatial harmony, the adaptive usage improves social interaction.

5.3.9	 **Figure 5.3.9. (a)** Existing Courtyard © author	 **Figure 5.3.9. (b)** Installation of a Community Lantern—Light of Unity	In the courtyard, lanterns made by regional craftspeople hang in a rhythmic pattern, signifying group involvement. The community's involvement in preserving heritage is symbolised by this installation. In keeping with the idea of adaptive reuse, it turns traditional decorative craft into a welcoming, interactive activity.
5.3.10	 **Figure 5.3.10. (a)** Existing Verandah © author	 **Figure 5.3.10. (b)** Small Outdoor Amphitheatre: The Courtyard Stage	Archival photos, sketches, and oral narratives are shown in translucent light boxes set into the walls of the passageway. The muted lighting inspires reflection and respect, turning the hallway into a chronology of history where memory and architecture coexist.

Table 5.1 Typical Analysis and Proposal for Spaces in a Wada

6. Discussion

Wadas' adaptive reuse demonstrates how traditional design can continue to be useful in meeting contemporary cultural and urban demands. Wadas have historically served as residences, offices, and gathering places for the community; this reflects a design intelligence based on social life, craft, and climate. These same characteristics make them perfect for repurposing as cultural and educational venues today. In order to prevent heritage structures from becoming static relics, this study places a strong emphasis on "preservation through activation," which ensures that they remain operational and socially engaged.

This research suggests reuse that combines minimal intervention with cultural participation, whereas previous conservation strategies frequently concentrated exclusively on structural repair. Wadas can be reincorporated into city life as living heritage rather than being isolated as monuments. By actively connecting the past and

present, their adaptive reuse strikes a balance between sustainability, usefulness, and authenticity.

Involving the community is essential to the longevity of culture. Wadas' function as gathering places is restored through local involvement, performances, and workshops. This strategy is in line with the "conservation through continued use" tenet of global heritage. Wadas' passive design, which includes courtyards, substantial walls, and shaded verandahs, naturally promotes sustainability in terms of the environment, and reuse lowers energy and material waste. In terms of the economy, restoration generates jobs in the area as well as chances for tourism and crafts.

However, policy gaps remain. Maharashtra still lacks comprehensive heritage regulations for privately owned vernacular buildings. Insufficient funding, limited awareness, and fragmented governance further hinder progress. A collaborative framework involving government bodies, academic institutions, and local communities is essential. Conceptually, the research reinforces heritage as a *living system*, where adaptation itself becomes conservation — ensuring continuity, identity, and resilience within changing urban contexts.

7. Conclusion and Recommendations

This study looked at adaptive reuse as a sustainable way to preserve historic Wadas, which are buildings that capture the architectural, environmental, and cultural wisdom of the Maratha era. Wadas still have a great deal of promise as living cultural assets, even in spite of their demise. By fusing preservation with functional relevance, adaptive reuse prolongs their existence and turns them into dynamic areas for community engagement, learning, and innovation.

The results demonstrate that, with careful utilisation, wadas can promote local economies, boost urban renewal, and enhance cultural identity. Minimal intervention, reversible design, and genuine workmanship should be the guidelines for reuse, and hybrid uses such as community centres, museums, and cafés should guarantee sustained participation. Public involvement, educational initiatives, and activities that revitalise the social function of these areas are all essential components of cultural conservation.

Equally important are policy measures. Maharashtra requires a comprehensive heritage policy that acknowledges privately owned and unlisted Wadas, provides funding for restoration, and implements zoning protection and digital documentation. To strengthen the basis for conservation practice, future research should incorporate socio-economic impact assessments, digital heritage mapping, and thorough field documentation.

Wadas' adaptive reuse essentially signifies both cultural continuity and preservation, converting old buildings into tenacious, neighborhood-driven relics that bridge the gap between traditional knowledge and the goals of contemporary urban life.

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Resilient Traditional Knowledge Systems in Architecture: Integrating Vernacular Practices in Contemporary Design in context of Wadas in Pune.

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Abstract: Traditional knowledge systems and local practices have been shaping the built environment in India, reflecting deep ecological wisdom, cultural continuity and community resilience. This study helps explore indigenous architectural built-form, material use and layout reflecting the cultural continuity and climate-responsive design rooted in their regional contexts, specific to "Wadas" as the traditional residential typology of built form in Pune.

Through a qualitative research methodology combining spatial analysis, literature review, case studies and online surveys, the paper examines the socio-cultural values embedded in traditional habitats of the Wadas in Pune.

By examining vernacular architectural form and socio-cultural values embedded in traditional habitats, the research looks at "Wada"as traditional residential built form in terms of its contemporary use in Pune.

The current research paper aims at looking at Wadas in Sadashiv Peth which continue being used for traditional private residential use, compared to Vishram baug as public use. The study also looks at a mixed use "Wada" case study from Erandwane which represents different era of Pune's Urban Evolution. The study also enquires whether adaptive reuse of Wadas has been a good practice in carrying the Architectural language defining the Climate and Culture of the land with today's contemporary use. This study concludes with emphasis on integrating vernacular principles into modern architectural discourse to foster environmentally adaptive and socially inclusive built environments to achieve sustainable, climate-responsive and culturally sensitive solutions for contemporary use of Wadas in Pune.

Keywords: Traditional knowledge system; cultural continuity; climate responsive, contemporary use, Wadas in Pune

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1. Introduction

The Architectural heritage of India is a major repository of cultural expression, ecologically intelligent and climate responsive built form. In Maharashtra, traditional built forms such as Wadas and vernacular homes embody centuries of adaptation to climate, local material and social structure. The pace of construction and the contemporary requirements of urban residents in dense areas have made cities look like

homogenous masses of blocks which have no stories to tell in terms of the climate nor cultural settings. This paper investigates how traditional knowledge systems can be resilient and inform sustainable design in contemporary contexts.

The focus of the current study attempt to understand the traditional architectural practices like Wadas in Pune in context of climate and culture. Also to study if adaptive reuse of Wadas has been a good practice in carrying the Architectural language defining the Climate and Culture of the land in today's contemporary use.

The objectives of study can be stated as:

- To examine traditional residential built form (Wada) in context of Pune, Maharashtra in context of environmental resilience and cultural continuity considering contemporary use.
- To study relevance of traditional residential built form like under adaptive reuse in Pune.
- To propose Recommendations for Heritage-Sensitive and Climate-Responsive Built Form.

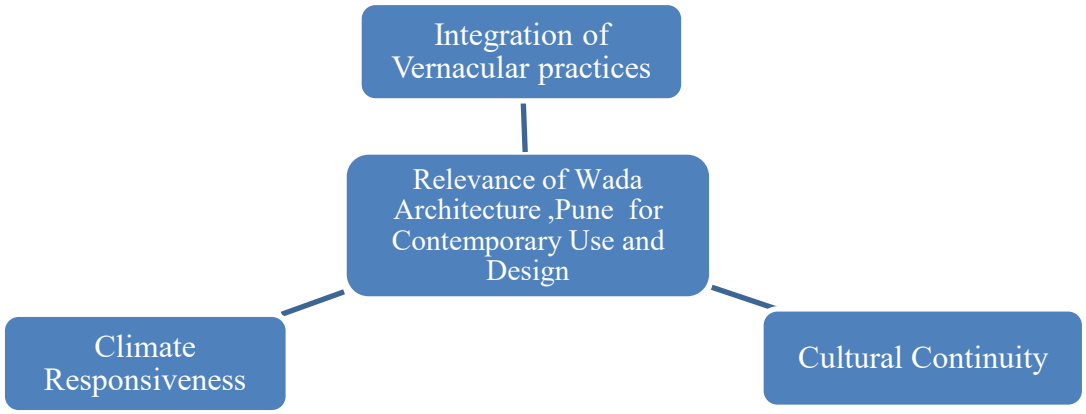


Figure 1. Resilient Vernacular Practices and Adaptability of Contemporary Design (Source: Author)

2. Research methodology

The study employs case study approach with qualitative analysis based on observations and surveys with residents and users.

Case study selection criteria: Wada houses in Sadashiv Peth Pune represent a stong historical context being one of the 17 original "Peths" established during the Maratha Peshwa era (17^{th}-19^{th} Century). Sadashiv Peth has a built form typology which is traditionally characterized by Wadas (built form with introverted courtyard) on deep, narrow plots. Today the area is transformed showing a mix of heritage structures and dense, midrise redevelopment projects. The Urban grain of this area is dense and fine grained with narrow historic lanes.

The Primary land use of Sadashiv Peth can be considered as "Mixed use" core with a high density of traditional markets, coaching classes, temples and small-scale commercial retail integrated with housing. The area illustrates Landmarks like Vishram baug, Bharat Itihas, Sanshodhak Mandal etc.

Vishram baug stands as an adaptive reuse project which is open to all (Public use as Museum) such as a restored Heritage which represents cultural roots of Pune's Maratha Architecture.

The study also takes a fresh overview at a Private Rented Adaptive Reuse of "Saraswati Niwas" which was traditionally used for Residential purpose but is transformed to a Media office which exemplifies the socio-economic and cultural realities of Pune city. This study looks at how traditional residences of Pune fit into the contemporary needs and realities today. This case study at Deccan is selected since it is located in a locality just 2km from Sadashiv Peth and represents a more modern, upscale suburb that developed significantly in the post-independence era. The built form typology is predominantly modern luxury residential apartments mid to high rise complexes and contemporary office buildings with glass and aluminium sliding facades. The Urban grain can be defined as Spacious and planned with wider roads like Karve Road and Law College Road. The primary land use can be defined as Premium residential land institutional, with prestigious educational institutes) and IT hubs alongside high-end housing. Landmark projects being Film and television institute of India (FTII)., Cummins, Dinanath Mangeshkar Hospital.

The methodology looks at these case studies and online surveys with residents or users to understand daily use patterns and spatial negotiations in contemporary use. The Spatial layout or use patterns is needed to understand the use, climate responsiveness, and socio-cultural symbolism of Wada architecture considering orientation, zoning (public/private), circulation, and climate comfort strategies.

3. Literature Review:

Vernacular Wada architecture in Pune represents a unique fusion of cultural heritage and climate-responsive design. The study of Contemporary use of traditional residential built forms in Pune highlights how traditional Wadas are being adapted to modern contexts, blending vernacular principles with new urban demands (Urban Précis, 2023). Technical studies further demonstrate the inherent sustainability of these structures, showing how their spatial organization, courtyards, and material choices respond effectively to Pune's climatic conditions (Vakharia & Joshi, 2023). Complementing these perspectives, accessible documentation of Wada features provides a comparative lens for understanding their architectural significance across Maharashtra, reinforcing their role as both cultural artifacts and living heritage (StudyLib, 2023). Together, these sources underscore the relevance of Wadas as models for integrating tradition and innovation in contemporary urban design and hence Pune city becomes a relevant case

to the study under “Resilient Traditional Knowledge Systems in Architecture” and also has potential to show way ahead in adopting how Vernacular Practices can be integrated in Contemporary Design.

Pune's *Wada* architecture represents and demonstrates cultural continuity and climate responsiveness of Maratha Architecture through traditional features like internal courtyards, thick walls, and teak wood use, designed for the region's hot-dry climate and fostering community life. These heritage structures offer sustainable blueprints for contemporary architecture despite challenges of urban pressure and deterioration. Use of lime plaster, basalt, teak wood, and laterite stone reflects ecological sensitivity and these materials also provide insulation, breathability and durability suited to Maharashtra’s varied climate zones.

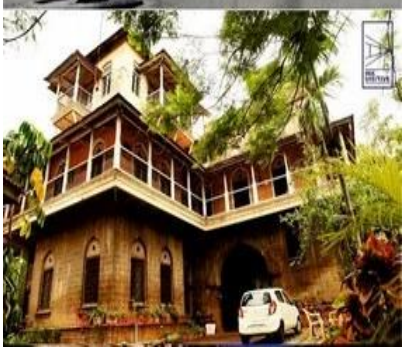


Figure2: VinchurkarWada 1925
Sadashiv Peth
(***source:*** ://www.facebook.com/groups/memoriesofpoona/posts/898667608203485); right –Today’s issues for Wadas in Pune: Deterioration-Legal and Policy hurdles –ownership and tenancy issues-balancing heritage and modernity in use and maintainace costs.

A critical aspect of Wada planning is the distinct zoning of public, semi-public, and private spaces Wadas were not just residences; they were “Social Hubs” centers for social interactions, administrative activities, and cultural functions. The central courtyards and large halls (Diwan-khana) facilitated these gatherings. The extensive and ornate wooden carvings on pillars, brackets, and facades demonstrate a shared cultural appreciation for meticulous craftsmanship, blending local techniques with Mughal, Rajasthani, and Gujarati influences. Thick external walls and narrow, strategically placed staircases; often hidden within walls were common defensive measures for Royal security, reflecting the political climate of the time.

The findings from the study indicate the original material palette, was based on available resources and historical influences. The material of construction is the core influencing factor to achieve high thermal comfort, low energy consumption and strong community orientation. Their evolution over time has introduced complexities in material use, occupancy, and change in use of Space.

Table 3.1. Material Timeline showing the transition and changing palette of material for construction and structural additions (Source: Author)

Peshwa Era (18th Century	Predominantly used local, sustainable materials		
	Basalt stone or mud	For thick walls and foundations	
	Teak wood	for load-bearing structures, columns, beams, ornate carvings, and balconies	
	Lime mortar	as the primary binding agent	
British Era (19th Century onwards	Introduction of new elements alongside traditional methods.		
	Cast-iron railings and glass windows	began to appear, influencing the facade designs	
	Simpler, less ornate designs	prominence as Maratha power waned	
Modern Era (20th - 21st Century	Repairs and new construction	often involve modern materials.	
	Reinforced concrete cement (RCC)	for structural additions and new buildings	
	The original material palette	often neglected in favor of faster, cheaper modern alternatives	Top to Bottom: Shaniwar Wada, Pune, Juna Wada; Gaikwad Wada ©Image Courtesy Inquisitive, Sarkar Wada (Courtesy Samanata Kumar) and Dhepe Wada ©Google Image; Windows of Wada Architecture (courtesy: Samanta kumar)

3.1. Case study 1: Sadashiv Peth

The traditional **Wadas of Sadashiv Peth** represent a critical layer of Pune's history, showcasing a unique architectural typology that is both climate-responsive and socially symbolic.



Figure 3. Sadashiv Peth, Pune
Source: https://www.alamy.com/stock-photo/sadashiv peth.html?pseudoid=12D2C55D8C9A47F1B34C0AC33C65DF89;https://www.squareyards.com/sadashiv-peth-in-pune-overview-832

3.1.1 Layout and Spatial Planning

Sadashiv Peth wadas are prime examples of traditional Maratha Architecture, focusing on community and climate. While following the courtyard system and privacy principles, they generally have fewer courtyards (often one or two) and a more compact layout due to typical urban space constraints compared to the sprawling 20,000 sq ft Vishrambaug Wada.

Courtyard system**:** The planning is introverted, with rooms arranged around one or more central courtyards (*chowks*). This creates a clear hierarchy from public to private spaces.

Zoning: Outer court for social gatherings and official business (*kacheri*) while Inner court reserved for the family, particularly women, rituals (*tulsi vrindavan*), kitchen, and private living areas.

Cultural Significance**:** The architecture fosters strong community bonds, with courtyards used for festivals, gatherings, and daily interactions. The discreet placement of staircases reflects the need for security and privacy in a joint-family setup.

Material and Construction **-** Thick stone/mud walls provide thermal mass to regulate indoor temperatures. The internal courtyards with natural cross ventilation and shaded verandahs facilitate natural light and passive cooling. Traditional knowledge system of these wadas is seen through the utilisation of passive cooling strategies.

3.2. Case study 2: Vishram Baug

A significant heritage structure in Pune, represents traditional Maratha architecture through its **courtyard layout, intricate teak wood carvings, and climate-responsive**

design. Its design reflects socio-cultural needs for privacy and communal life, offering valuable lessons for contemporary sustainable architecture in Pune. As the luxurious residence of Peshwa Baji Rao II, it has a sophisticated layout with three successive courtyards that strictly defined these zones, ensuring maximum privacy for women and inner family life. The first court was for public audiences (Diwan-khana), the inner ones for family.

Layout and Spatial Planning: The Wada (mansion) spans 20,000 sq. ft. and is a prime example of introverted planning, characteristic of traditional Maratha residences.

3.2.1 Courtyard System:

The core of the design revolves around **three internal courtyards** (*chowks*) that provide natural light, ventilation, and a sense of tranquility, adhering to principles of Vastu Shastra. This design creates a microclimate, passively cooling the structure.

3.2.2 Zoning:

The layout follows a strict functional and social zoning, separating areas into public, semi-private, and private zones. Traditionally the outer court was for public gatherings and administrative functions and the inner courts were for private family life.

Privacy and Security: Staircases are discreetly placed between thick brick walls to ensure privacy, especially for women, and enhance security. The street-facing facade is relatively stark, giving little away about the luxurious.

3.2.3 Cultural Significance:

Vishrambaug Wada holds immense historical and cultural importance as the luxurious residence of Peshwa Baji Rao II, the last Peshwa of the Maratha Confederacy. It is a symbol of Peshwa power and architectural grandeur, having witnessed key events in Maratha history. The structure currently houses a museum and serves as a cultural center, hosting various events that promote local Culture and Art.

3.2.4 Materials and Construction:

The Wada's construction highlights the use of locally available, durable materials. The structure is primarily built using teak wood, basalt stone, bricks, and lime mortar. The Key features include intricately carved wooden pillars (often cypress-shaped and made from single teak trees), ornate ceilings, and a terracotta facade. The Craftsmanship is seen through its detailed carvings and decorative elements which showcase artistic excellence and skilled craftsmanship of the Maratha period, blending influences from Mughal, Rajasthani, and Gujarati styles.

Table 3.2. Comparison between Architectural study aspects of the built form:

(**Source:** Author)

Architectural study aspect	Vishrambaug Wada (Sadashiv Peth)	Typical Sadashiv Peth Wadas
Scale	Grand, opulent mansion (20,000 sqft)	Smaller residential units
Courtyard	Three distinct courtyards for strict zoning	Typically, one or two courtyards
Ornamentation	Highly elaborate wooden carvings and ornate balconies reflecting royal status	Significant but generally less extravagant woodwork
Function	Former royal residence, now a museum and government offices	Primarily residential, some facing commercial adaptation/neglect
Climate features	Incorporates fountains/pools for enhanced cooling	Relies on core Wada features: courtyards, thick walls, verandahs
Architectural expression today	Conversion of historic residences into offices or cultural centers	Thick walls, internal courtyards, natural ventilation, shaded verandahs
Vernacular Design Adaptability	Preservation of architectural identity, reduced material waste, enhanced urban aesthetics.	High thermal comfort, low energy consumption, strong community orientation
Traditional Vernacular Resilience	Economically viable, environmentally sustainable, culturally rooted.	Adaptable to climate, socially inclusive, and structurally durable
Summarizing Key Findings	**Represents Cultural Continuity in Wada Architecture**	**Represents Climate Responsiveness in Wada Architecture**

4.0 Discussion:

4.1 Reuse Strategy and Stakeholders:

Vishram Baug has undergone various adaptive reuse strategies throughout its history, housing a college, a high school, a post office, and municipal offices. Existing Building use accommodates a post office, some Pune Municipal Corporation (PMC) offices, and a museum of Maratha artifacts.

Adaptive Reuse Approach: Conservation and management plans focus on adaptive reuse to ensure the structure remains a "living monument".

Stakeholders: Key stakeholders involved in its management and conservation include the Pune Municipal Corporation (owner and manager), the heritage committee (advisory role), local community members, historians, architects, and visitors.

4.2 Vishram Baug

Vishram Baug stands out as a prime example of Adaptive Reuse with following key highlights how Contemporary Use can co-exist with Design adaptability.

4.2.1.a Traditional Knowledge for Contemporary Built Forms

The architectural design of Vishrambaug Wada provides sustainable and climate-responsive lessons applicable to modern Pune.

4.2.1.b Climate Responsiveness: The use of thick walls, high ceilings, and central courtyards for natural cooling and ventilation are highly relevant in the local climate.

4.2.1.c Spatial Qualities*:* The balance of public and private spaces, as well as features like *jaalis* (latticed screens) and *jharokhas* (projecting balconies) that provide light, airflow, and privacy, can inform contemporary space planning.

4.2.1.d Sustainable Materials: The emphasis on durable, locally sourced natural materials like teak and stone offers a model for sustainable material use in modern construction.

4.2.1.e Aesthetics and Identity: Integrating traditional aesthetic elements like carved wooden motifs and structured grid planning can help contemporary architecture foster a sense of cultural continuity and identity in Pune's rapidly urbanizing.

Maratha Wadas are not just climate-responsive shelters but living cultural systems. Their adaptive reuse demands sensitive strategies that honor both tangible and intangible heritage.

4.3 Sadashiv Peth Wadas:

The Peth has evolved from a residential area for elite Brahmin joint families to a densely populated, mixed-use zone. The Occupancy layering over the period of time has gradually shifted from being the place of large joint families who occupied the entire Wada with specific areas dedicated for specific functions, rituals or routine tasks. However, Economic pressures and changing family structures led to the subdivision of wadas into multiple rental units or tenements (*chawls*), often compromising the original layout and structure and give it a very fragmented space appearance due to changed patterns of functions and diverse users. Further to this, many have ‘change of use’ at ground floor by conversion from residential to shops, small businesses, or offices, creating a complex mix of private residential and commercial activities.

4.3.1 Adaptive Reuse and Contemporary Challenges:

4.3.1a Deterioration: A significant percentage of wadas are in poor or dilapidated condition due to age and lack of consistent maintenance, posing safety risks.

4.3.1b Legal/Policy Hurdles: Many wadas lack legal protection, as only a few monuments like Shaniwar Wada are nationally protected. Strict regulations around

protected sites (e.g., ASI buffer zones) can hinder necessary repairs or redevelopment efforts by private owners.

4.3.1c Ownership and Tenancy Issues: Fragmented ownership and complex tenancy law, with many long-term tenants paying very low rents, make it difficult to get consensus for major renovations or cluster redevelopment initiatives.

4.3.1d Balancing Heritage and Modernity: The main challenge is finding viable adaptive reuse solutions like -boutique hotels, cultural centers, homestays, Art craft museums or exhibition or Art Galleries that preserve the architectural integrity while meeting modern functional and safety requirements



Figure 4. Traditional residential typology in suburban areas like Erandwane-Deccan area: Saraswati Nivas –No.20, Prabhat Road, Deccan, Pune
Courtesy: Ashwini Teranikar, Director, Lead Media & publicity pvt.ltd

5. Conclusion

These case studies exemplify traditional Maratha Vernacular architecture where **climate responsiveness and cultural continuity are intrinsically linked through common architectural elements, such as courtyards, thick walls, and intricate woodwork**. While both cases share these core principles, Vishrambaug Wada, as a royal residence, exhibits features on a grander, more ornate scale compared to the slightly smaller, though still substantial, Wadas of the general aristocratic populace in the surrounding peth.

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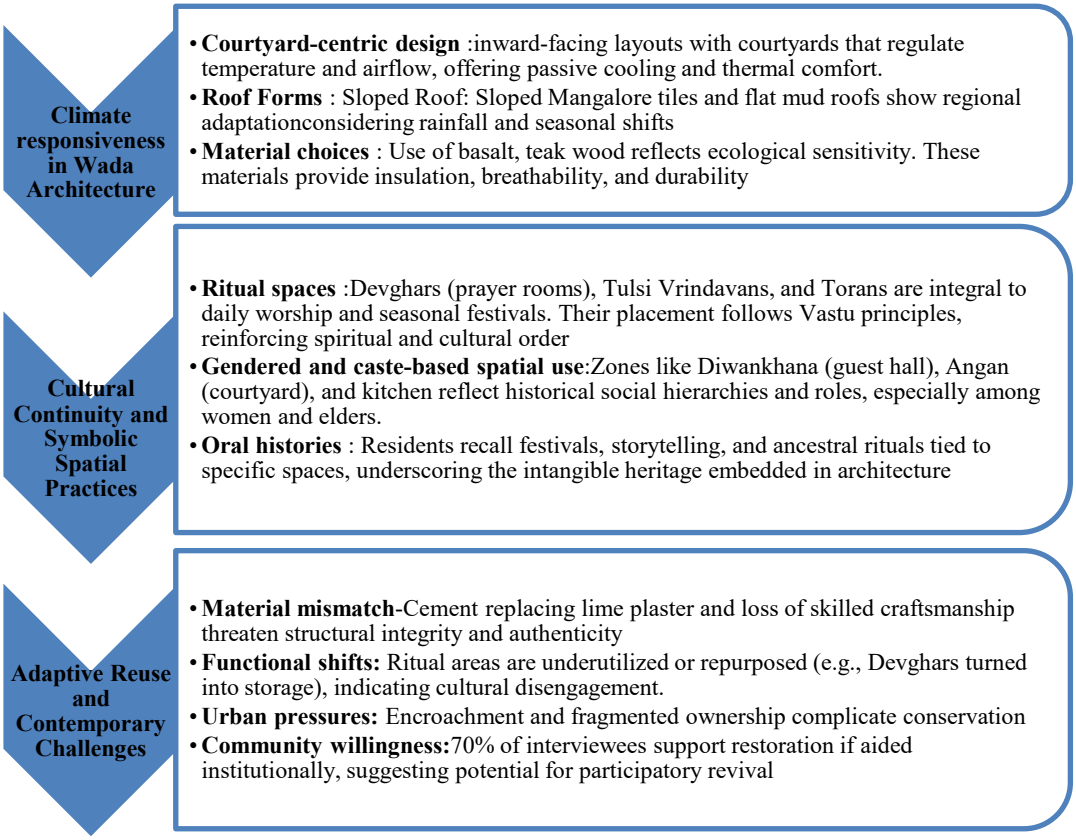


Figure 5. Summarizing the key aspects of Vernacular practices: Climate Responsiveness. Cultural Continuity and Adaptive Reuse and how it can reinforce adaptability in Contemporary Design (***Source:*** Author)

5.1 Climate Responsiveness achieved through Traditional Vernacular built form:

The wada architecture is a testament to sustainable, passive cooling strategies perfectly suited to Pune's hot semi-arid climate with hot summers, monsoon and mild winters.

The courtyard or chowk is the central, shared climatic feature. The open-to-sky courtyards act as a "convective thermostat," moderating the microclimate. They facilitate air circulation both horizontal and vertical cross-ventilation and bring in natural, diffused light to surrounding rooms. In the hot season, water sprinkled in the courtyard or small fountains and pools (often found in the first courtyard of grander wadas like Vishrambaug) aid evaporative cooling. Both Vishrambaug Wada and other Sadashiv Peth wadas utilize high thermal mass materials. Thick walls made of basalt/granite stone or brick masonry and timber structures (teak columns, beams) help keep interiors cool by absorbing heat during the day and releasing it at night.

Further, Large verandahs and intricately carved wooden balconies (prominent in Vishrambaug's facade) provide essential shade from the intense sun and shelter from rain, while also acting as transitional spaces. Traditional narrow but tall windows are designed to capture wind flow at lower levels and provide a view from a seated position, a cultural norm.

5.2 Cultural Continuity executed through spatial organization and practices:

The architectural style and spatial organization of the wadas reflect the socio-cultural ethos and joint family system of the Maratha Brahmin aristocracy during the Peshwa era.

5.3 Adaptive Reuse and Contemporary Challenges:

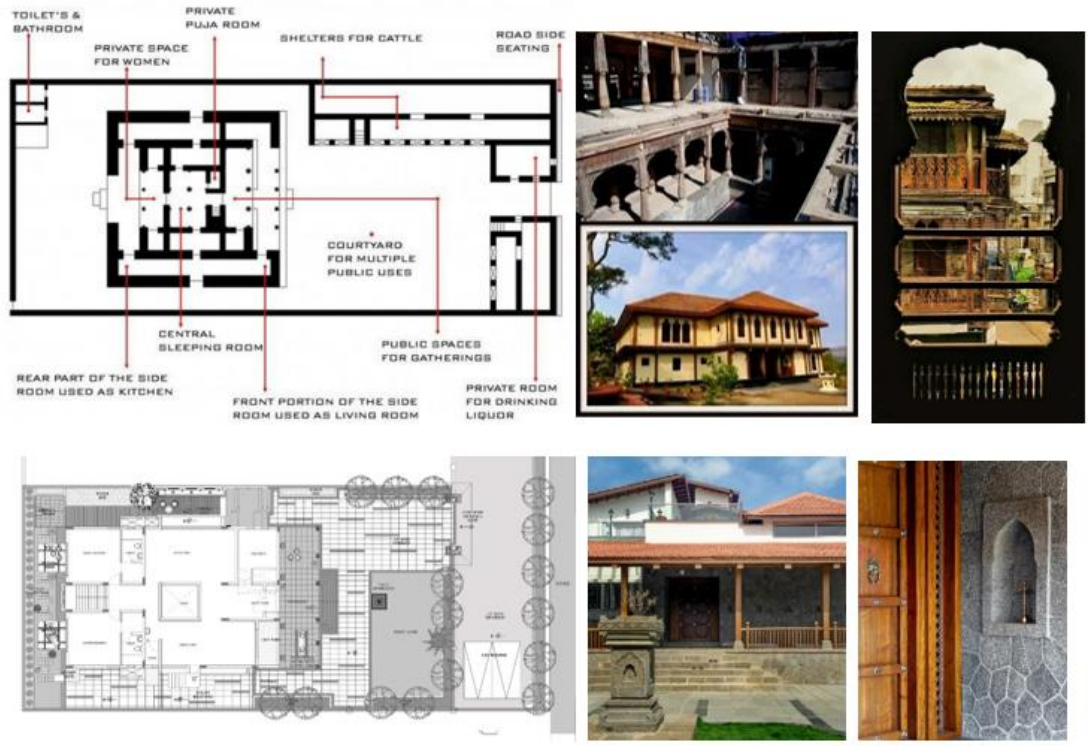


Figure 6. Typical plan of a Wada in Maharashtra (top left);
Source: The Architecture of Wadas of Maharashtra - RTF | Rethinking The Future ; typical Wada courtyard ,built form and window details; Chavan Wada -Contemporary look of Wada inspired Private residences in Pune

Adaptive reuse with integration of traditional spatial logic (e.g., courtyards, shading) informing modern layouts in Contemporary Design and use of local materials and passive design strategies in new construction. The Barriers being Regulatory constraints, lack of awareness and modernisation pressures; and Opportunities being Policy support, community engagement, educational integration. A design framework proposal is needed based on a hybrid model combining vernacular wisdom with modern technology for resilient urban habitats.

5.4 How can traditional vernacular strategies be Relevant and Applicable to Contemporary Built Forms

The Wadas offer a blueprint for sustainable, community-centric urban living in modern Pune and Adaptive Reuse integrating Vernacular strategies making the goal of climate

responsiveness achievable along with assurance of "Cultural Continuity" through continuation of the experience of the built form inspite of the change in use as per current needs and time.

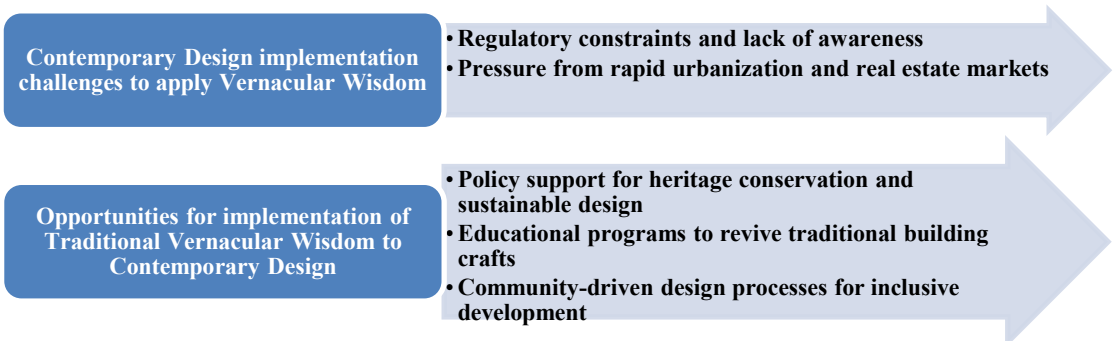


Figure 5.3. Contemporary design challenges and Opportunities for application of Vernacular Wisdom
(**Source:** Author)

5.4a Sustainable Design: Lessons from climate-responsive design (courtyards, thermal mass) can be integrated into contemporary sustainable buildings.

5.4b Community and Identity: The urban form's emphasis on communal spaces and local identity offers insights into fostering social interaction in modern high-rises, which often lack this.

5.4c Adaptive Reuse: The potential for adaptive reuse of existing structures as museums or cultural spaces can help the city retain its heritage while addressing modern needs like at Vishram Baug.

Above three aspects help address the changing needs of socio-economic and cultural realities.

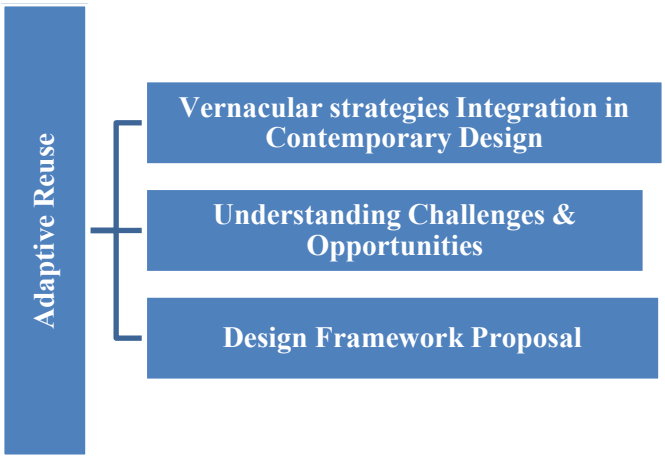


Figure 5.4. Adaptive Reuse: Vernacular strategies integrated in contemporary Design
(**Source:** Author)

Thus, Maratha Wadas are not just climate-responsive shelters but living cultural systems. Their adaptive reuse demands sensitive strategies that honor both tangible and intangible heritage.

5.5 Way Ahead in Design Framework for Application of Vernacular strategies applied to Contemporary design.

A hybrid design model needs to be proposed that combines vernacular wisdom with modern technology considering Key components as Climate-responsive planning, Cultural contextualization, Material sustainability and Community participation. Traditional knowledge systems in Maharashtra's built environment offer invaluable lessons in resilience, sustainability, and cultural continuity. By studying Wada architecture and adaptive reuse practices, this paper demonstrates the relevance of vernacular design in addressing contemporary urban challenges. Integrating these principles into modern architectural discourse can lead to built environments that are not only environmentally adaptive but also deeply rooted in cultural identity.

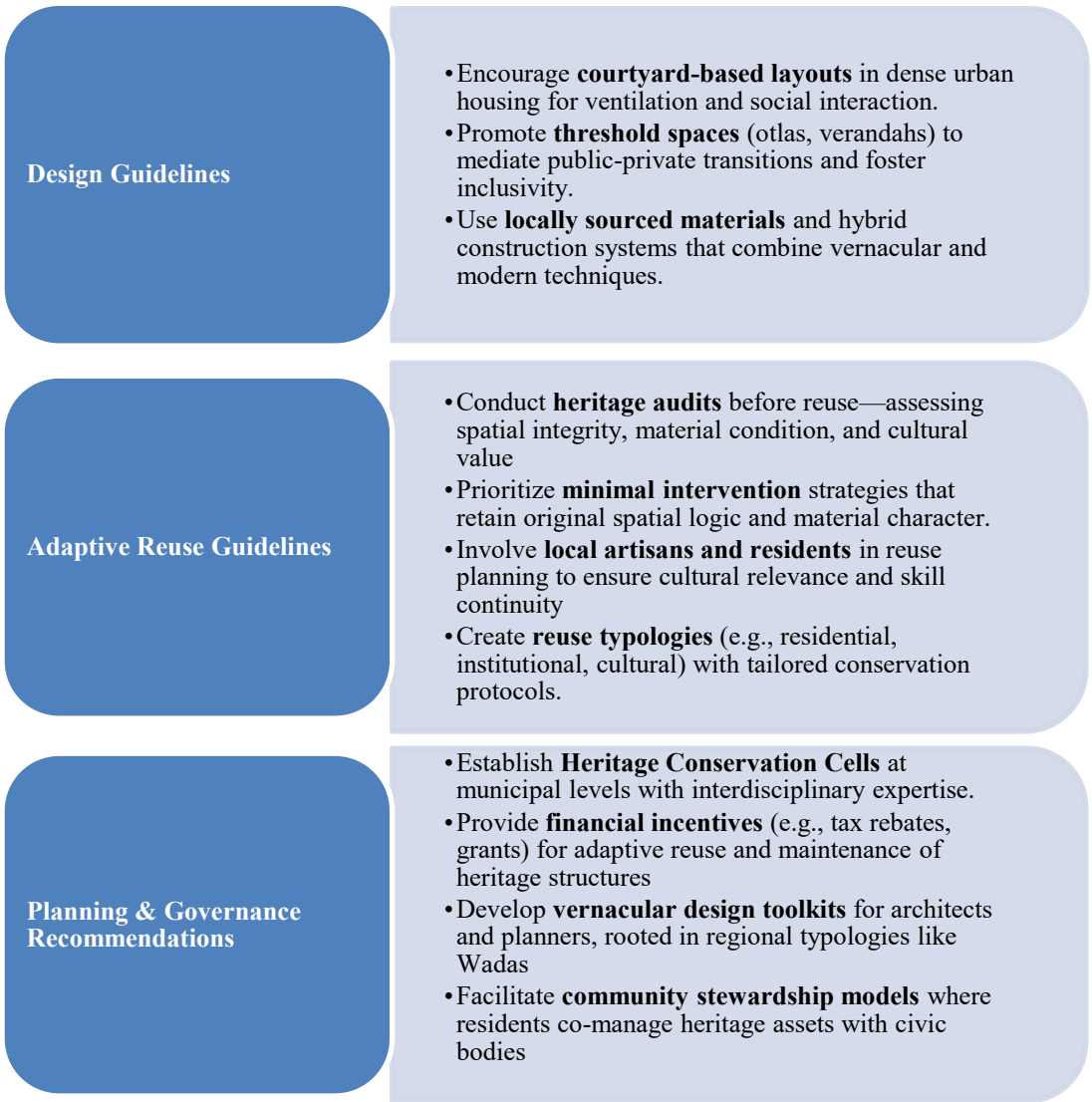


Figure 5.5. Recommendations for Heritage-Sensitive, Climate-Responsive, Socio-Culturally Inclusive Built Form
(**Source:** Author)

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Exploring urban identity through public buildings: A Case Study of Elevated Pune Metro stations

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Abstract: Public buildings often transcend their functional roles to embody cultural values and shape the identity of a city. In Pune, a city profoundly anchored in history yet fast modernizing, elevated metro stations have emerged as a major aspect reshaping its visual and cultural landscape. This study investigates the ways in which these stations – in particular, P. M. C., Deccan, Nal Stop, Vanaz and Elevated Civil Court – help to create a modern urban identity that is in harmony with the city's past.

Based on Kevin Lynch's "The Image of the City" theory, the study looks at how landmarks, nodes, and pathways affect how people perceive and understand metropolitan areas. A literature review, case study analysis, onsite inspections, public impression surveys with thirty respondents, and expert interviews with five professionals are all part of the research approach. The objective is to assess how people's emotional and geographical ties to the city are shaped by design language, materiality, and cultural symbolism.

Results show that stations like P. M. C. and Deccan, which have Pagdi themes and traditional Wada – inspired architecture, provide consumers a great sense of pride and belonging. Within the context of contemporary infrastructure, these features enable commuters to connect with the city's Maratha legacy. On the other hand, stations like Deccan and Nal Stop are seen as essentially functional with little emotional resonance since they lack symbolic articulation.

According to the analysis, Pune Metro is progressively creating a new "metro identity" that combines history and modernity both visually and experientially. The study comes to the conclusion that integrating cultural expression into public infrastructure improves a city's imageability and intelligibility, strengthening the bond between residents and their physical environment and fostering a unified, enduring urban identity.

Keywords: Kevin Lynch; Pune Metro; Urban Landmarks; Cultural Identity; and Public Perception.

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1. Introduction

The dynamic interplay of people, place, and architecture shape urban identity. Public buildings frequently serve as symbolic anchors that symbolize civic advancement and cultural continuity in India's fast urbanizing cities (Mehrotra R. , 2011). Among these, Metro stations have become new architectural typologies that combine urban representation with infrastructure. They serve not just as transport crossroads but also as public areas that establish the visual and experiential identity of cities (Curtis W. J., 2018).

With the construction of the Pune Metro, Pune, which has long been regarded as a center of culture and education, is going through a significant transition. The project reshapes the city's spatial order and aesthetic identity, signaling a move towards transit-oriented urbanism (Patil J. , 2022). Metro stations – through their visibility, scale, and architectural language – have begun to redefine how citizens perceive the city's growth and modernity (Rao M. , 2023).

This research draws from Kevin Lynch's seminal theory 'The Image of the City' (1960), which highlights five key elements – paths, edges, districts, nodes, and landmarks – that contribute to the imageability and legibility of the urban environments. In the context of Pune, metro stations can be interpreted through these elements: as paths guiding movement, nodes as activity, landmarks of recognition and edges between neighborhoods (Lynch K. , 1960).

The problem addressed in this study lies in the limited understanding of metro architecture as a catalyst for identity and memory in Indian cities. While studies on transport systems often prioritize engineering and efficiency, few address the experiential and symbolic dimensions of metro design practices that align with people's cognitive and emotional connection to the city (Amin A. , 2011).

Therefore, this research aims to explore how Pune Metro stations contribute to the urban identity of the city through their architectural, spatial, and perceptual attributes. The objectives include analyzing selected metro stations through Lynch's theoretical lens examining public and expert perceptions using photo-questionnaires, and evaluating how these stations redefine the visual and experiential fabric of Pune. By doing so, the study situates metro architecture as an emerging form of public building that simultaneously serves function, representation, and meaning – and embodiment of the contemporary Indian city's evolving image (Prakash V. , 2022); (Patel S. , 2022).

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2. Literature Review

2.1 Urban Identity and Sense of Place

The term "urban identity" describes how individuals view and relate to the physical and cultural features of the city. Common symbols, communal memory, and architectural imagery are frequently used to convey it (Relph E. , 1976); (Norberg-Schulz C. , 1980). According to Montgomery (1998), the way that people perceive their city is shaped by the interplay of form, activity, and meaning. Strong "imageability" cities, according to Lynch (1960), are more memorable because of the way their physical characteristics – paths, nodes, landmarks, edges, and districts – support attachment and direction. According to recent research, urban identity is also linked to inclusivity and sustainability, where areas represent both past and future goals (Amin A. , 2011); (Prakash V. , 2022).

2.2 Public Architecture and Civic Representation

Public structures are essential for expressing civic pride and shared values. They serve as representations of community identity, democracy, and accessibility (Vale L. J., 1992). According to Mehrotra (2011), public architecture frequently acts as a mediator between traditional aesthetics and modern goals in Indian towns. In emerging infrastructure typologies like transportation hubs, where symbolic and functionality coexist, this dual role is particularly evident (Curtis W. J., 2018); (Rao M. , 2023). The significance of public architecture in forming civic consciousness is demonstrated by its capacity to determine the visual identity of cities (Banerjee T. , 2019).

2.3 Kevin Lynch and the Concept of Imageability

Understanding how people create mental images of their surroundings is still largely based on Kevin Lynch's 1960 book "The Image of the City". Paths, edges, districts, nodes, and landmarks are the five structural components Lynch identified as contributing to the legibility and imageability of cities. These concepts have been developed further in later studies, which have connected them to cognitive perception, emotional mapping, and wayfinding (Appleyard D. , 1973); (Banerjee T. , 2019). In order to study contemporary infrastructure settings, such as metro systems, whose legibility hinges on architectural clarity, signage, and spatial rhythm, contemporary studies reinterpret Lynch's thesis (Kalpan, 2019); (Zhang Y. , 2022).

2.4 Transit Architecture as Urban Landmark

These days, transit systems serve as more than just means of transportation; they are symbols of contemporary urban identity. Because of its prominence, design aesthetic, and cultural integration, metro stations in particular are considered architectural icons (Edwards B. , 2011). Globally, famous transit projects that show how transit hubs reshape urban character include Santiago Calatrava's PATH Station in New York and Foster's Canary Wharf Station in London (Rattenbury K. , 2018). Emerging metro

networks in India are being rethought as civic areas that combine practicality and beauty. In Lynchian terminology, they serve as nodes and landmarks that improve navigating and add to the city's mental image (Sharma J. &., 2020); (Patel S. , 2022).

2.5 Metro Architecture and the Indian Urban Context

Due to India's fast urbanization, metro systems are now important infrastructure initiatives that are changing the character of cities (Patil J. , 2022). Metro stations serve as new urban anchors, incorporating native materials and themes with contemporary design vocabulary, according to studies conducted in Delhi, Bangalore, and Hyderabad (Prakash V. , 2022); (Rao M. , 2023). Pune Metro in particular is an example of how forward-thinking ideas and heritage awareness may coexist. Its architecture establishes recognizable monuments within the changing urban fabric through form, material, and public interface. According to academics, integrating contextual aesthetics and readable spatial planning into metro architecture enhances citizen's sense of pride and belonging (Amin A. , 2011); (Banerjee T. , 2019).

3. Methodology

This study adopts a qualitative and interpretative research approach to examine how Pune Metro stations function as urban landmarks contributing to the city's evolving identity. It investigates not only the architectural form but also the cultural symbolism and public perception attached to these metro stations.

1.Design of Research: Using Kevin Lynch's theoretical framework of pathways, nodes, and landmarks, the exploratory study aims to comprehend people's mental images of the city. The study evaluates how metro stations affect Pune's imageability and readability by combining visual and perceptual evaluations.

2.Selection of Case Studies: Five elevated Pune Metro stations were chosen: Deccan, Elevated Civil Court, Nal Stop, Vanaz, and P. M. C. These stations, which represent a cross-section of Pune's cultural and urban diversity, were selected based on their visibility, architectural uniqueness, symbolic design elements, and everyday foot traffic. To access how each site's architectural language interacts with the surrounding urban fabric, photos, sketches, and design observations were taken.

3.Techniques of Gathering Data: To provide a thorough understanding, the study incorporates data from primary and secondary sources.

- Primary Data:

  - **Public Perception Survey:** Conducted with 30 respondents from diverse backgrounds including students, professionals, and daily commuters. The survey explored their perception of metro stations as city landmarks and their emotional connection with them.

- **Expert Interviews:** Conducted with three professionals – an architect, an urban planner, and a cultural historian – to gain insights into architectural symbolism and contextual relevance.

- **Field Observations:** Visual and behavioral observations were made to analyze user movement, façade visibility, and public interaction around the selected stations.

- Secondary Data:

- Review of literature, articles, reports, and design guidelines related to urban identity, landmark theory, and Pune's architectural history.

4.Tools and Techniques:

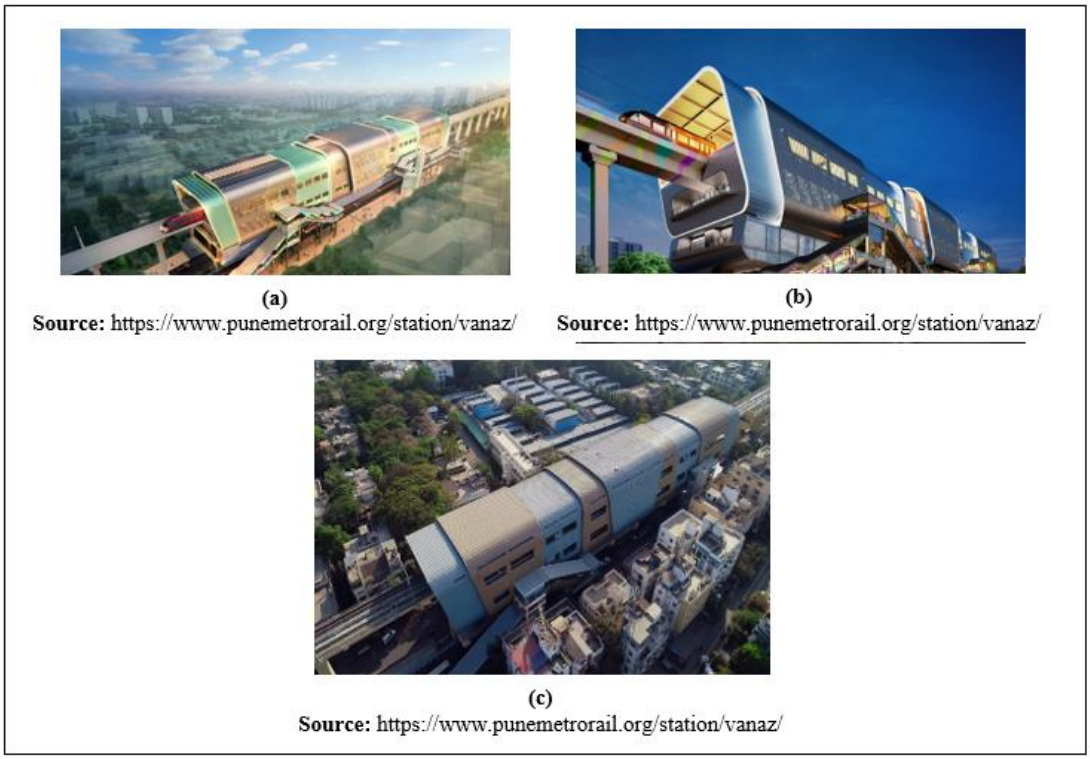
- **Structured Questionnaire** for the public survey, focusing on familiarity, perception, and visual identity of metro stations.

- **Semi-Structured Interviews** for expert insights into design intent, cultural expression, and urban impact.

- **Photographic Documentation** for recording architectural elements, materials, and urban context.

3.1 Vanaz Metro Station Case Study

Vanaz Metro Station, located at the western terminal of the Purple Lin, acts as a critical anchor point between the residential neighborhoods of Kothrud and the larger mobility network of Pune. As an elevated station, it introduces a new architectural scale to an area dominated by mid-rise housing, commercial edges, and institutional buildings. The station's structural expression – consisting of exposed girders, concrete piers, and a linear platform volume – creates a visible landmark that redefines the visual skyline of Kothrud. Its integration with surrounding bus routes, residential streets, and pedestrian walkways demonstrates how elevated metro architecture becomes an agent of urban identity formation by improving accessibility and reinforcing the area's civic character. The presence of shaded entry pods, street – level landscaping, and organized vehicular movement further contribute to a more legible public realm, reflecting the transition of Pune from a traditional city to a modern, transit-oriented urban fabric.



(a)
Source: https://www.punemetrorail.org/station/vanaz/

(b)
Source: https://www.punemetrorail.org/station/vanaz/

(c)
Source: https://www.punemetrorail.org/station/vanaz/

Figure 1: (a), (b) Architectural View of Vanaz Metro Station; (c) Work Progress Update of Vanaz Metro Station – January 2023

3.2 Nal Stop Metro Station Case Study

Nal Stop Metro Station occupies a highly vibrant urban junction known for its commercial activity, educational institutions, and cultural landmarks, and cultural landmarks like theatres and performance spaces. The elevated station introduces a new layer of public infrastructure above an already dense and dynamic environment. Its architectural form, though utilitarian, negotiates with the mixed-use surroundings by providing wide concourses, efficient vertical circulation, and structured pathways for pedestrians. The station becomes a mediator between fast-moving vehicular corridors and slow-moving pedestrian activities. By organizing movement and offering shaded, accessible interfaces, the metro station enhances the cultural identity of Nal Stop as a social node where public life converges. In doing so, the station doesn't simply provide mobility – it strengthens the recognizable identity of the junction as a multifunctional urban hub connected by modern public transport.



(a)
Source: https://www.punemetrorail.org/station/nal-stop/



(b)
Source: https://www.punemetrorail.org/station/nal-stop/



(c)
Source: https://www.punemetrorail.org/station/nal-stop/

Figure 2: (a), (b) Architectural View of Nal Stop Metro Station; (c) Work Progress Update of Nal Stop Metro Station – September 2022

3.3 Deccan Gymkhana Metro Station Case Study

Deccan Metro Station is situated within one of the Pune's most historic and socially active precincts – Deccan Gymkhana. The elevated station introduces a contemporary public building into an area shaped by institutional landmarks, sports facilities, and dense commercial streets. Architecturally, the station appears as an elevated spine running to Jangli Maharaj Road, presenting a long, streamlined built form. Its visual presence contributes to a new urban rhythm along the road while maintaining continuity with the existing pedestrian flows. The station enhances the identity of Deccan as a place of cultural convergence by supporting walkability, creating safer crossings, and offering a more structured transport experience. Its placement transforms the corridor into a multimodal urban strip, reflecting how modern transit buildings can reinterpret the historic and cultural essence of an established neighborhood.

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(a)
Source: https://www.punemetrorail.org/station/deccan-gymkhana/



(b)
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(c)
Source: https://www.punemetrorail.org/station/deccan-gymkhana/

Figure 3: (a), (b) Architectural View of Deccan Gymkhana Metro Station; (c) Work Progress Update of Deccan Gymkhana Metro Station – September 2022

3.4 P. M. C. Metro Station Case Study

P. M. C. Metro Station gains additional significance due to its proximity to the Pune Municipal Corporation headquarters. As an elevated public building adjacent to a major civic institution, the station helps reinforce the administrative identity of the city. The architecture of the station – bold, functional, and highly infrastructural – contrasts with the formal civic architecture of the P. M. C. building, resulting in an interesting dialogue between old and new forms of governance-related public architecture. The station improves accessibility for citizens visiting the municipal complex while offering a structured, democratic space for daily movement. Its footpaths, shaded stairways, and integration of last-mile modes reflect how public transit structures contribute to the civic experience. By enabling smoother citizen interactions with administrative spaces, P. M. C. station actively strengthens the collective identity of this precinct as the governing heart of Pune.



(a)
Source: https://www.punemetrorail.org/station/pmc/



(b)
Source: https://www.punemetrorail.org/station/pmc/



(c)
Source: https://www.punemetrorail.org/station/pmc/

Figure 4: (a), (b) Architectural View of P. M. C. Metro Station; (c) Work Progress Update of P. M. C. Metro Station – September 2022

3.5 Elevated Civil Court Metro Station Case Study

Civil Court Metro Station plays a pivotal role in shaping the identity of Pune's central civic precinct. Positioned near major institutions such as the District Court, Sassoon Hospital, and soon-to-be-developed transit interchange, the station introduces a contemporary public building into an area long defined by administrative and judicial functions. Although the overall system includes both elevated and underground elements, the elevated portions significantly contribute to the visual character of the surrounding urban fabric. The station's structural clarity, long-span deck, and exposed infrastructural profile establish it as a prominent feature on the skyline, marking the area as a key point of convergence.

This metro station serves as an important multimodal node, linking metro travel with buses, rickshaws, pedestrian paths, and the broader railway network. By organizing movement and creating efficient vertical circulation, the station enhances accessibility to nearby civic institutions, thereby strengthening their public interface. Its presence transforms the precinct from a car-dominated zone into a more walkable, connected environment. In this way, the Civil Court Metro Station becomes more than a transit facility – it contributes to a renewed civic identity, symbolizing Pune's aspiration toward integrated and modern urban governance.

4.Findings and Analysis

a. For Public Perception

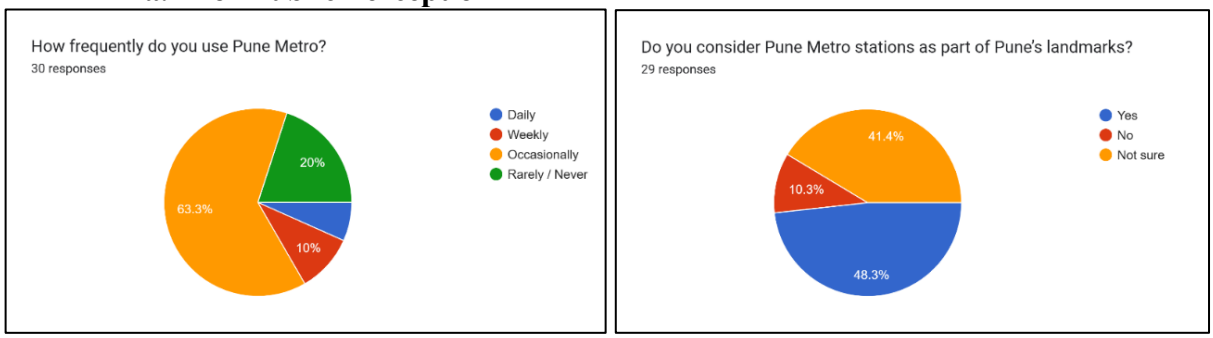


Figure 7. Recognition of Metro Stations as Landmarks

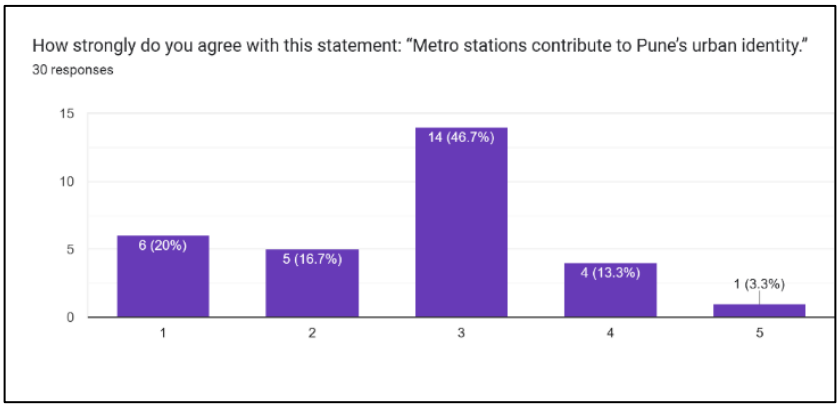


Figure 8: Contribution of Metro Stations to Urban Identity

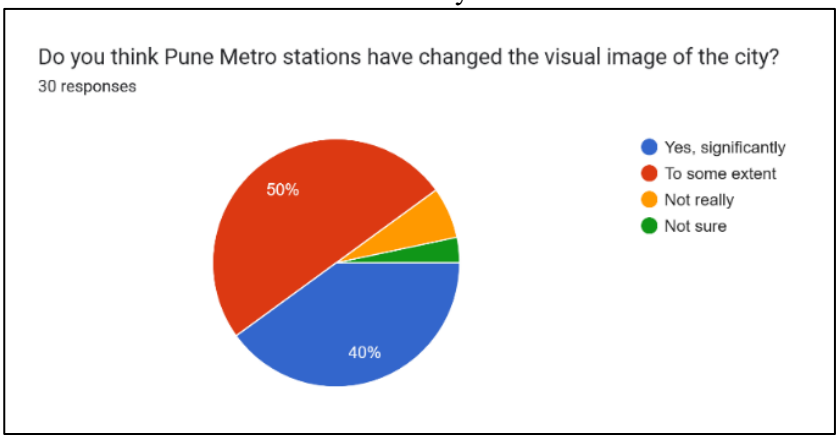


Figure 9: Change in Visual Image of the city

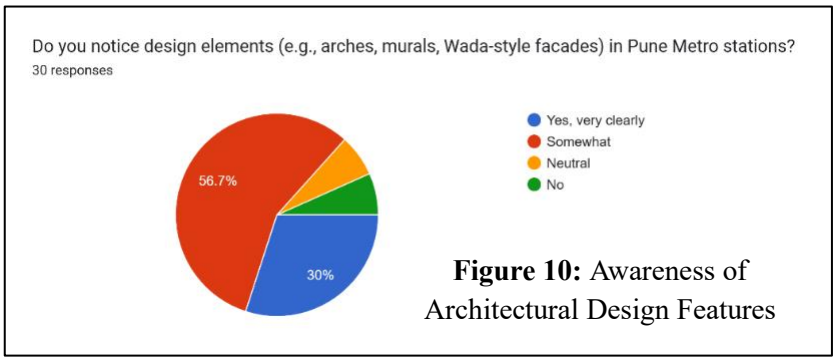


Figure 10: Awareness of Architectural Design Features

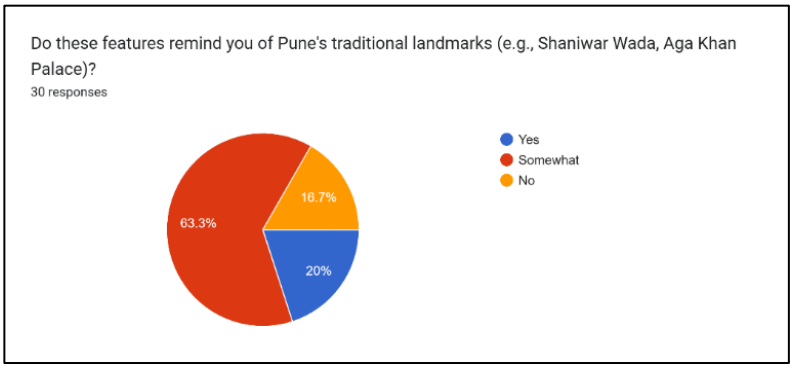


Figure 11: Cultural Association of Metro Stations

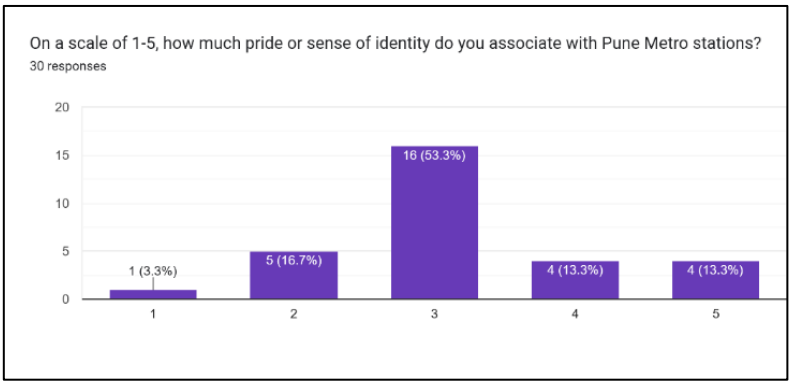


Figure 12: Level of Pride and Identification

- Thirty people participated in the public poll, the majority of whom were students between the ages of 18 and 25 who occasionally ride the Pune Metro. According to the comments, metro stations are not seen as representations of cultural identity but rather as markers of convenience and advancement. Fewer people thought the metro reflected the city's history or personality, but almost 70% agreed that it had altered Pune's urban image.

- Only a small percentage of respondents observed design features like arches or murals connected to historic monuments like Shaniwar Wada, although stations like P. M. C., Nal Stop, and Deccan were commonly mentioned as identifiable landmarks because of their location and visibility. Although the majority of respondents liked the sleek, contemporary appearance, they thought the cultural allusions were "surface-level" or sparse.

- Metro stations serve as new landmarks in daily life, as evidenced by the fact that about 60% of participants utilized them as reference points. But the emotion of attachment or pride stayed mild, averaging about a 3 out of 5. Respondents suggested including more regional materials, public art, and Marathi motifs to strengthen cultural connection. In general, the metro is viewed by the people as Pune's contemporary identity that is still developing into a cultural one.

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b. Expert Review

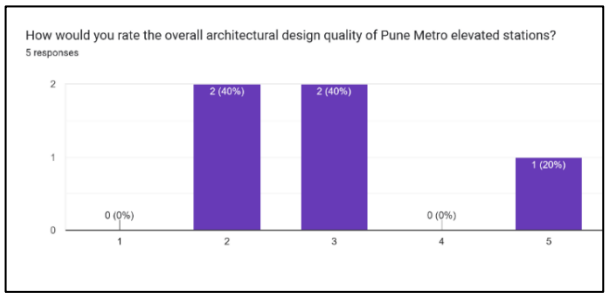


Figure 13: Overall Design Quality Perception

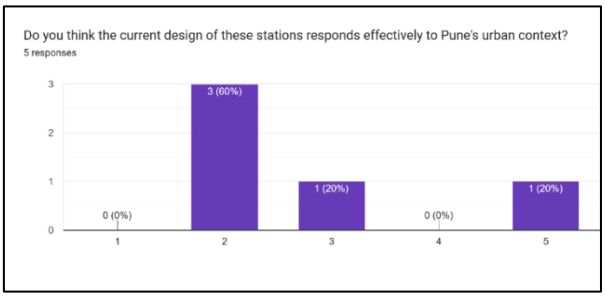


Figure 14: Contextual Response of Metro Stations

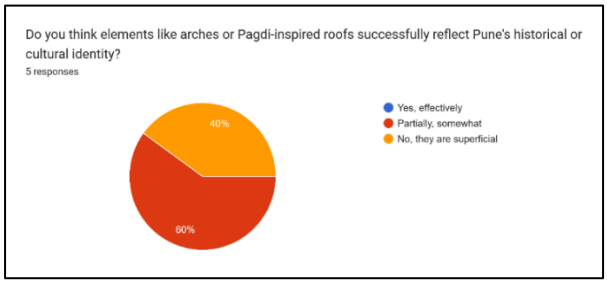


Figure 15: Cultural Representation through Design Elements

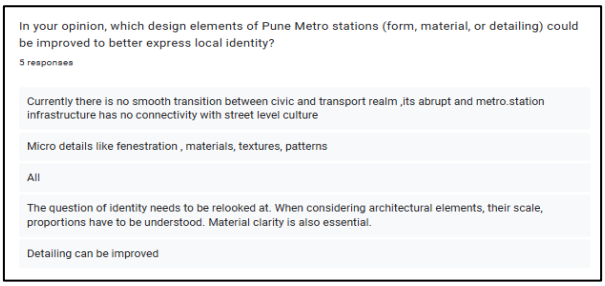


Figure 16: Recommended Areas for Improvement

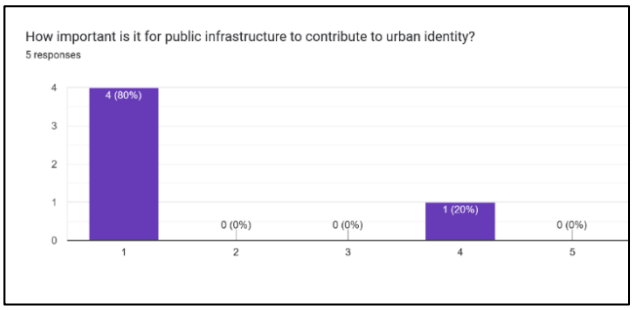


Figure 17: Priority of Public Infrastructure in Urban Identity

- Five experts – an engineer, an architect, and an urban designer – offered their opinions. They said the metro's design was effective but lacked context. Experts believed that although gestures like arches and Pagdi-shaped roofs were acknowledged, they were shallow and failed to convey the essence of Pune's architectural legacy.
- Experts noted that stations seem disconnected from their environment, implying that each ought to react to the personality of its precinct. They observed lost chances to incorporate public areas and urban cohesion and gave the design quality an average assessment (2-3 / 5).
- Experts generally concurred that the Pune Metro symbolizes a contemporary identity as opposed to a cultural one. To strengthen metro stations as urban anchors in Pune's landscape, they suggested context-based designs, better façade details, and integration with daily life.

6. Conclusion

- According to the survey, Pune Metro stations are progressively becoming new makers of urban identity, signifying a change in the way people view the city both aesthetically and culturally. Because of their size and prominence, elevated metro stations are increasingly serving as identifiable monuments that shape the perception of the city. Stations like P. M. C. and Deccan have started to position themselves as urban reference points that link Pune's contemporary growth routes with its historic core. This shift is not uniform, though, since many stations continue to be essentially utilitarian buildings with no connection to the city's architectural and cultural core.
- It is clear from public opinion that most people see the metro as a symbol of modernization and progress rather than as a continuance of Pune's traditional identity. Although efficiency, convenience, and cleanliness are valued by users, there is currently no cultural or emotional bond with these stations. However, experts stress that although there are attempts to incorporate cultural symbols like arches or true essence of Pune's rich architectural and social fabric.
- The significance of context-sensitive design in public infrastructure is shown by this discrepancy between design purpose and user perception. As noticeable features of the urban environment, metro stations ought to convey the essence and narrative of the city in addition to making travel easier. When carefully considered, the incorporation of local materials, murals, public art, and vernacular references can turn these transit areas into civic landmarks that strengthen a sense of identity and belonging.
- In summary, Pune Metro has enormous potential to influence how a city that is changing quickly is perceived by the public. Subsequent metro designs must embrace a human-centered, culturally embedded approach in order to fortify this relationship, moving beyond standardized, technical solutions. Public infrastructure transcends its function and becomes an enduring emblem of collective metropolitan identity when it speaks to the everyday lives, memories, and pride of its residents.

AI Usage Disclosure

The authors acknowledge the use of artificial intelligence (AI) tools during the preparation of this paper. Specifically, ChatGPT (GPT-5) and Grammarly were utilized solely for grammar correction, language refinement, and minor structural improvements to enhance clarity and readability.

No part of the research content, analysis, interpretation, or conclusions was generated by AI. All core ideas, arguments, and findings presented in this paper are entirely the original work of the authors.

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Religious Heritage in India: Threats, Perceptions, and Authenticity

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Abstract: Religious heritage in India is characterised by remarkable diversity and vibrant living traditions, situated at the confluence of myth, ritual practice, and cultural identity. These sites function as repositories of collective memory, embodying centuries of history and tradition. Although local and state authorities continue to implement beautification and maintenance initiatives, the broader challenge of sustaining cultural continuity remains insufficiently addressed. The widely critiqued "monument-in-the-garden" approach often produces decontextualized and contrived representations of sacred places, diminishing their experiential authenticity. In contrast, preserving historic contexts and lived traditions enables deeper engagement with a site's cultural significance.

This study investigates contemporary stakeholders' perceptions of religious heritage in India, focusing on how cultural authenticity and continuity are negotiated alongside the pressures of beautification, urbanization, and tourism. When heritage sites are distanced from the functions they historically fulfilled, they risk losing essential qualities of character, integrity, and authenticity. Drawing on survey-based research, the paper examines attitudes toward ritual practices, site character, and visitor expectations, while also exploring experiences of disillusionment conceptually resonant with "Paris Syndrome" among visitors.

By situating heritage within both governance and psychological frameworks, the study contributes to ongoing debates on authentic continuity, touristification, and heritage management. It proposes pathways for practice that safeguard religious traditions while ensuring their continued relevance in contemporary contexts.

Keywords: Religious Heritage; Authenticity; Perceptions; Conservation; Beautification; Paris Syndrome.

1. Introduction

Religious heritage in India is unique and has distinct position and role to play. These sites are not only representative examples of the past but also living sites where rituals, identity and memory exist together.

These places draw up devotees from around the world, and they function as important centres for pilgrimage, worship etc. Alongside their spiritual significance, these places are also celebrated for their rich cultural traditions, historical strength, and distinctive architectural heritage (Singh & Kollarath, 2024)

The Sacred sites are not just places of religious importance; they are vibrant cultural and social hubs that reflect and preserve the spiritual traditions and cultural heritage of particular faiths or belief systems.

When Interventions are to be undertaken, the usual focus remains on visual refinement, tourist friendly access rather than deeper cultural continuity which had been the reason the defining the place. Scholars like Dr. Amita Sinha warn against the "Monument in garden" approach which treats the heritage site as a object of display rather than as a living environment rooted in tradition (Sinha, 2016)

Such interventions tended to dimmish or touch the authenticity of the place which is broadly understood as the degree to which heritage values are "truthfully and credibly expressed" through attributes like materials, use, traditions, setting and spirit (UNECO)

Many visitors arrive at these sacred sites with a certain level of expectation however they encounter transformations which are guided by modernisation, touristification, crowd management and commodification of the site. This leads to a mismatch between the perceived idea/ expectations and the reality. This phenomenon is termed as Paris Syndrome. There seems to be a significant gap in research which examines how the visitors perceive authenticity, their level of awareness about ongoing interventions and comparison between the expectations and experiences.

To address this gap, the present study was conducted. A a mixed-method investigation of religious heritage sites in India specifically where interventions have been done or are proposed was conducted by surveying visitors to weigh their perceptions of authenticity, interventions, and experiential alignment; and collecting opinions

The study examines how visitors understand authenticity at religious heritage sites. It also explores the extent to which current /planned intervention such as the corridors, beautification projects etc are noticed by visitors. It also examines whether these changes have an impact on the meaning associated with the site. The research considers whether disagreements between visitors' expectations and actual experiences indicate "Paris Syndrome".

2. Literature Review

Religious heritage in India is not static, its living, dynamic in nature and is generated by ritualistic use, social factors and memory. These sites are often not limited to the

built environment, but go beyond architecture suggesting context, continity and community participation.

Authenticity:

Authenticity is a foundational concept. It is one of the most discussed, debated concept in heritage studies. The Nara Document on Authenticity stresses that "Authenticity is an essential element in defining accessing and monitoring cultural heritage" (The NARA document on authenticity, 1994). Experts are of the opinion that living heritage requires an approach centred on continuity rather than restoration of heritage sites.

Literature indicates a move from fixed, object-centred definitions towards dynamic, perception-based understandings of authenticity, It shows that what is considered "authentic" is generally created by communities, visitors, and conservation frameworks

Living Heritage:

The concept of living heritage shifts the focus from static preservation to dynamic continuity. It requires an approach which focusses on continuity rather than mere restoration of heritage sites. Living heritage refers to sites that maintain continuity, meaning they are active and integrated within the life of the community (Yiran, 2018) . Nara Document of Authenticity also includes spirit and feeling as one of the criteria in defining authenticity apart from "form and design", "materials and substance", "use and function", "traditions and techniques", "location"

Interventions and Heritage

Scholars comment that redevelopment strategies for imposing visual equivalence while erasing layered, lived cultural landscapes. Literature on tourism indicates that redevelopments often transform these spaces into tourist destinations, which further affects its use. Tourism introduces new pressures and opportunities at the same time for heritage conservation. Researchers believe that tourism driven development leads to commodification of heritage sites which alter existing fabric and at times meet visitors' expectations.

A phenomenon known as Paris syndrome comes into play when crisis of expectation versus lived reality comes into existence. Visitors have been visiting religious heritage sites for multiple reasons. An image of the site is usually created based on past experiences, literature and media sources. At times the sites fail to represent visualized images, initiating a debate over what constitutes authentic experience.

Such experiences and visual based and at times contribute in diluting the continuity that is the core idea which defines living heritage.

3. Methodology

The study adopted a mixed methodology design combining quantitative survey with expert interpretations. This approach was found to be appropriate for perception-based heritage study as measurable attributes along with interpretative insights shape understanding

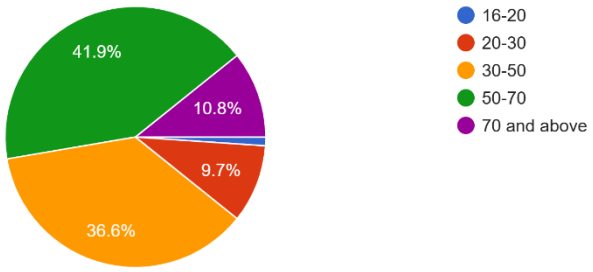
To record measurable attributes about visitor perceptions, an online google form based structured questionnaire was designed and shared online. Sites currently undergoing proposed interventions such as, corridor projects, and beautification, urban redevelopment were selected for the study.

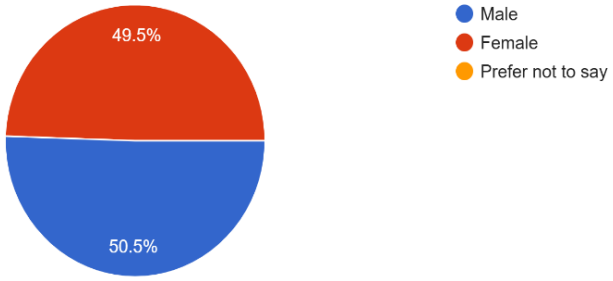
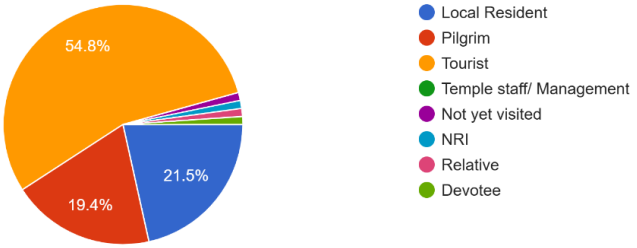
A total of 92 responses were collected. Respondents included tourists, pilgrims, and residents, this ensured representation of diverse visitor categories, consistent with heritage perception research

These responses were across five major pilgrimage sites: Pandharpur (26), Tuljapur (23), Varanasi (22), Jagannath Puri (13), and Ayodhya (8).

This patterns of visitation provides a balanced base for analysing the data.

4. Findings

Demographics: Age  **Figure 13** *Demographic data; Age of respondents*	The age distribution of respondents indicates that most visitors to religious heritage sites belong to older age groups. The largest segment is 50–70 followed by 30–50 years this accounts for nearly 80% of the sample. Younger respondents are relatively few, with

Gender Distribution across the sample  **Figure 14.** *Respondents Gender*	The gender distribution was also balanced distribution with almost equal weightage to males and females.
 **Figure 15.** *Category of visitors*	Tourists form a major category of visitors followed by Pilgrims and devotees
Site visited  **Figure 16.** *Site visit completed*	Sites visited in hierarchy by the respondents • Pandharpur • Tuljapur • Varanasi • Jagannath Puri • Ayodhya
Reasons for Visiting : Profile of Respondents	more than half of the respondents were visiting these sites for prayer, rituals, and devotional practices. A substantial group also visited with the intention of exploring the site as tourists,

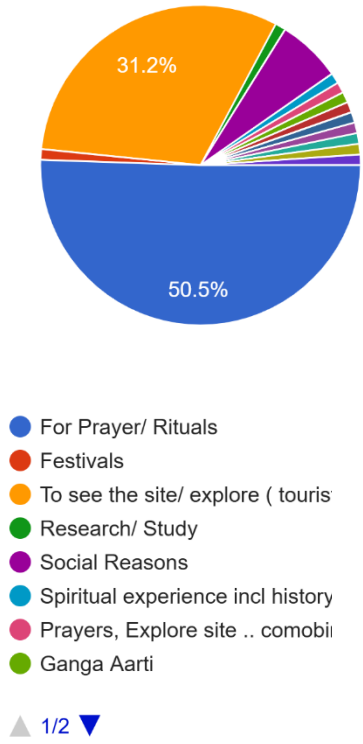


Figure 17. *Reasons for Visiting: Profile of Respondents*

these visitors tended to evaluate physical changes, accessibility, and cleanliness more clearly than the ritual-oriented group of people. smaller group of respondents indicated social or community-related reasons for their visit a very few respondents mentioned different reasons such as research, sculpture appreciation, attending festivals, witnessing Ganga Aarti, or viewing deity as reason for visiting the site

Awareness of ongoing/ planned interventions

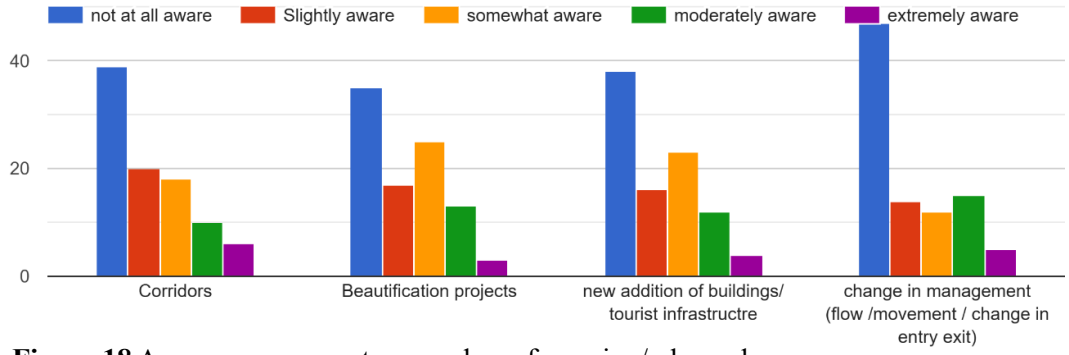


Figure 18 Awareness amongst responders of ongoing/ planned

A low to moderate level of awareness can be noted on the sites visited. For corridor works, beautification projects, new tourist infrastructure, and changes in movement routes, the largest group consistently reported being not at all aware. This indicates most of the visitors connect with religious heritage sites without sufficient knowledge decisions or interventions shaping them as most of them visited the site for religious reasons too

Site retaining character and originality

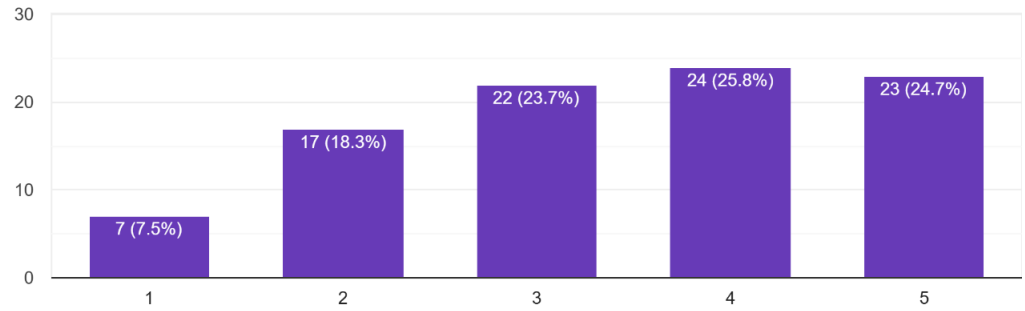


Figure 19 *Respondents opinion about retention of character and originality*

On scale of 5 -
5 indicates maximum retention of character and originality where, as 1 indicates no retention of character and originality of the site

Interventions (corridors, beautification, demolitions) effect on sense of connection to the site's history

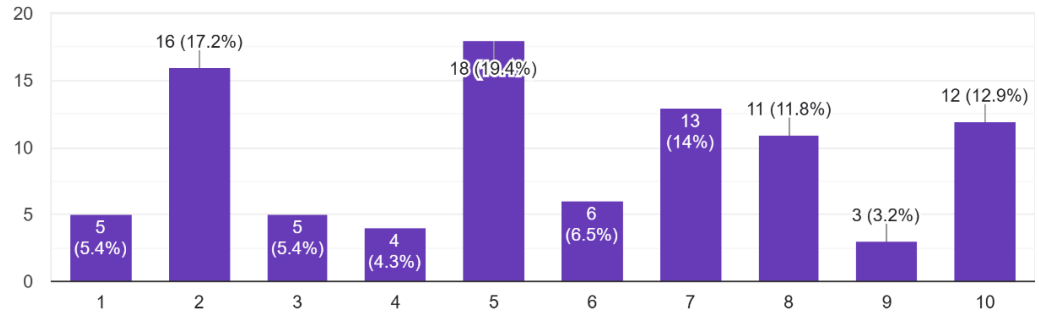
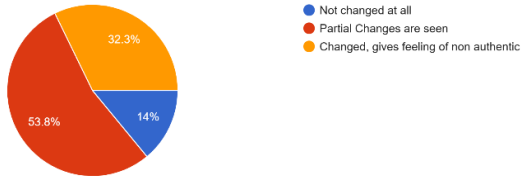


Figure 20 *Respondents' opinion about ongoing interventions which affect sense of connection*

Changes observed



Majority of the respondents noticed changes . though partial changes were noticed on a large scale, a sense of non-authentic character can be said to be felt by visitors.

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Authenticity as perceived by respondents

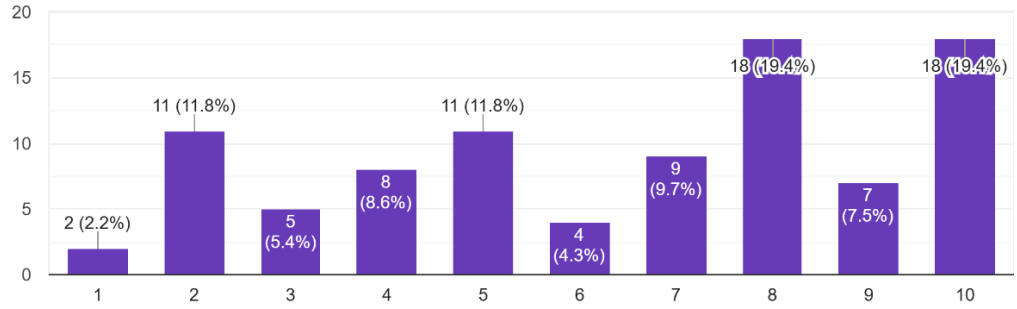


Figure 21. *Authenticity as perceived by respondents*

On scale of 10,
10 indicates maximum and 1 is not at all

Factors which contribute towards authenticity

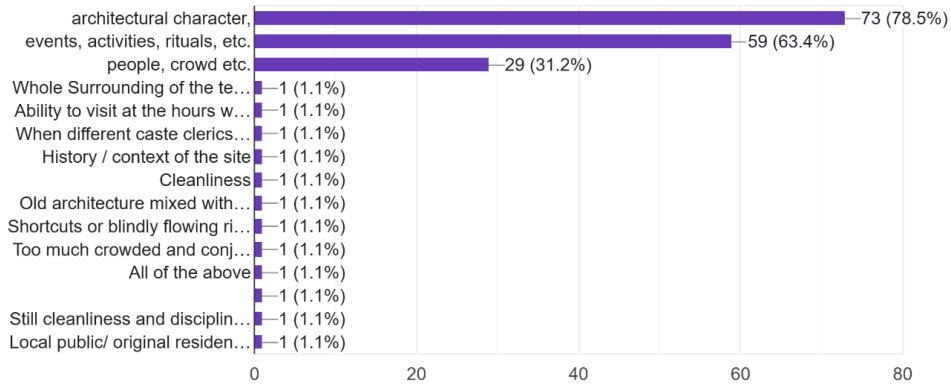


Figure 22. *Factors that contribute towards the perception of authenticity of the space as per the respondents*

Respondents associate authenticity primarily with features that retain the site's original character and cultural connection. Architecture is one of the prominent indicator of authenticity

Many participants also indicated that the intangible elements, such as rituals, community practices, and local narratives, are important in making feel authentic.

Overall, respondents view authenticity as a combination of physical preservation and the continuation of cultural practices, suggesting that both tangible and intangible heritage

People seem to feel that different parts of the site have changed to different degrees. The physical features like the newer buildings or the pathways are mostly seen as only moderately different, ssuggests that that even though changes are visible, these places continue to look familiar and true to their original form.

In contrast, how people *use* the space such as activities and eventsmovemnet patterns and enter and exit points are viewed as having changed a lot.

Expectations before visiting the site

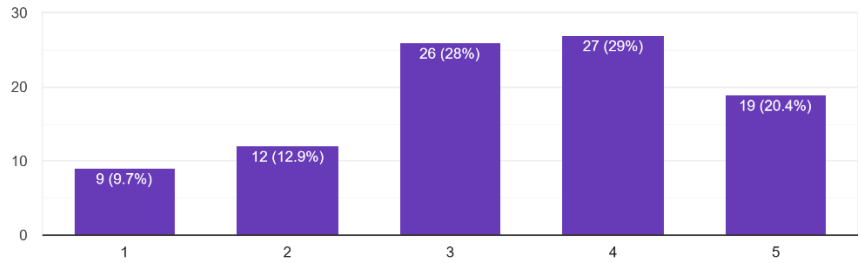


Figure 23. *Respondents scale of expectation before visit*

On scale of 5,
5 indicated maximum level of expectations whereas 1 indicated least expectations

Actual Experience

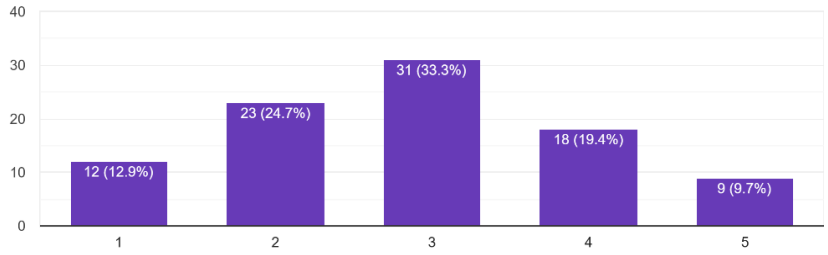


Figure 24. *Graph showing respondents experience match with expectation*

On scale of 5
5 indicates complete match of expectations to the experience whereas 1 indicates least match of expectations with experience

The above Two questions from the survey indicate the expectation and experience difference

It suggests that many visitors feel some mismatch between anticipated and on-site experience. This mismatch supports the "Paris Syndrome

5. Discussion

The key findings suggest that visitors' perception of religious heritage sites in India in complex and multi layered. These sites are vital spaces of worship, identity. However, they are now being shaped by process of development, beautification, tourism-oriented planning and also focusses on crowd management and commercial development. Responses also indicate that the changes are not uniform. For some cleanliness, comfort are on priority whereas for other that is disturbing and introduces sense of artificial nature.

Respondents have noted that demolition of old by lanes, traditional houses, shops, new additions of architectural components have disturbed the continuity of historic sites. These modifications seem to break the extended continuity of the religious heritage site which once might have existed. Amita Sinha's (Singh & Kollarath, 2024) argument of "Monument in garden" where the site is isolated from the context and seen as stand-alone is strengthened.

The next significant finding is about crowd management and movement patterns. Many responded that these have been changed, altered the experience and spiritual ambience which in turn affects the engagement and emotional contentment. It should be noted that when ritual participation is regimental, sense of connection diminishes. This in turn affects the perceived authenticity of the the site. This concern is in tune with concerns on heritage management which focus on preserving intangible components as an important aspect in safeguarding physical environment.

The findings also reveal that corridors and beautification efforts are received differently by stakeholders. Cleanliness, safety, visitor management is well recognized by most of the visitors. Respondents expressed concerns of the aesthetic or cultural appropriateness.

Another important finding of the study identifies the expectation – experience mismatch. It is in tune with the theme of psychological phenomena known as Paris Sydrome. The quantitative data indicates gap in it.
Paris Syndrome commonly associated with tourists whose expectations do not match with the reality. This can be adapted to Indian heritage context. For pilgrims, the heritage is not merely a place of interest; it is beyond that. Thus, when visitors encounter excessive touristification, commercialisation, changes in ritual access, the feeling of artificially reconstructed, may result in worry or rational conflict.

The study also suggests strong visitor preference for contextual design and preservation. Respondents repetitively highlighted the need to retain heritage identity, preserve old buildings, and minimize commercialisation. Respondents' suggestion of "better preservation of historic elements" and "design interventions that align with the site's character" shows that they appreciate change when it is informed and meaningful.

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6. Conclusion

The study indicates that the development of India's religious heritage sites produces complex responses among visitors. clean, organised infrastructure is appreciated by many however people feel that these changes, when insensitive to historical context, tend to diminish the spiritual and cultural authenticity which is central heritage sites.

Heritage policies thus should go beyond aesthetical beautification and should priorities continuity, contextual responses and overall lived experience.

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Evaluation of application of LiDAR Technology in Architectural Heritage Documentation

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Abstract: LiDAR, Light Detection and Ranging, is a remote sensing technology. It works by emitting laser pulses and measuring the time it takes to return from an object. LiDAR provides accurate spatial and structural data by creating highly accurate 3D maps and models which can be then used for disaster management, urban planning, environmental studies, architectural heritage conservation etc.

Various types of LIDAR technologies are used in architectural heritage conservation are listed here. Terrestrial Laser Scanning (TLS) Ground-based, stationary laser scanners mounted on a tripod, Mobile LiDAR Scanning, laser scanners mounted on a moving platform (vehicle, trolley), Airborne LiDAR (ALS) laser scanners mounted on aircraft or drones (UAV-LiDAR), Handheld / Backpack LiDAR (SLAM-based LiDAR) Portable scanners using SLAM (Simultaneous Localization and Mapping) technology, Bathymetric LiDAR which uses green wavelength lasers to penetrate water.

This research aims to evaluation of LiDAR technology in Architectural Heritage Documentation. The objectives of research are to evaluate the application of LiDAR in selected heritage case studies such as Rani ki Vav and the Qutb Minar complex, to analyse user's perspectives on LiDAR, focusing on operational challenges, data processing limitations, cost implications, and technical skill requirements.

The research covers two layered methodologies with case study analysis of UNESCO world heritage sites documented using LiDAR technology like Rani KI Vav, Gujrat and the Qutb Minar complex, Delhi and structured questionnaire-based survey to evaluate the application of LiDAR technology in architectural heritage documentation, its challenges, limitations, accuracy, speed, and cost-effectiveness. The research will provide architects with both empirical evidence from case studies and practical insights from professionals experienced in using LiDAR. The research fills the gap between technology promise and architectural practice, providing architects with actionable knowledge for using LiDAR in heritage documentation and restoration.

Keywords: *LiDAR, Architectural Heritage Documentation, Conservation*

1. Introduction:

Digital recording, documenting, and preservation are becoming increasingly important as our natural, cultural, and built heritage is threatened by conflict, natural disasters,

climate change, and careless human activities. (Remondino, 2011) (Vacca, 2023). The maintenance and conservation of historic structures are becoming more challenging due to geometrical complexity, degradation of materials, varying historical construction techniques, environmental pressures (Adamopoulos & Rinaudo, 2021). In recent years, advances in image and range-sensing technology have tremendously aided the preservation and study of architectural and natural heritage.

1.1 History of digital documentation of Heritage structures:

The Digital Michelangelo Project (1998–1999) was one of the first significant efforts to digitally capture large cultural and architectural objects in 3D using laser-range scanning technology.(Levoy et al., 2000). In early and mid-2000's Photogrammetry and scanning with formal guidelines for heritage-sector scanning were developed which was applied to capture Stonehenge carvings on sarsen stones, producing sub-millimetre-resolution point clouds. (Archaeology., Stonehenge Laser Scans, n.d.). Destruction of the Bamiyan Buddhas (Afghanistan) in 2001 sparked global awareness of the vulnerability of heritage, highlighted the importance of digital preservation and 3D documentation of at-risk monuments. Zamani Project by University of Cape Town in 2004 initiated the spatial digital documentation of cultural heritage sites and landscapes using terrestrial laser scanning (TLS), photogrammetry, GIS and other methods with aim to provide heritage communication, training and capacity building for experts and the public so that they have access to high-quality spatial heritage data, and can learn from, conserve, and protect heritage. (Zamani Project, n.d.). Scottish Ten Project was launched in 2010 to digitally document ten heritage sites (five in Scotland, five overseas) using 3D modeling. From 2015 to 2020 documentation process adopted use of drones with terrestrial laser scanning for complex heritage mapping giving accurate documentation.(Wang & Zakaria, 2025). Cultural Heritage Preservation and Restoration using Digital 3D Models programe was launched in 2019 at IIT Gandhinagar for conservation of cultural artifacts and monuments. (Raman, 2019). 3D for Heritage India project was launched in 2020 aimed at using LiDAR and digital documentation to build resilience and preserve heritage housing and structures (CEPT Research and Development Foundation (CRDF), n.d.).

1.2 LiDAR, (Light Detection and Ranging) and Types of LIDAR technology:

LiDAR, Light Detection and Ranging, is a remote sensing technology. It works by emitting laser pulses and measuring the time it takes to return from an object. LiDAR provides accurate spatial and structural data by creating highly accurate 3D maps and models which can be then used for disaster management, urban planning, environmental studies, architectural heritage conservation etc.

Various types of LIDAR technologies are used in architectural heritage conservation are listed here. Terrestrial Laser Scanning (TLS) Ground-based, stationary laser scanners mounted on a tripod, Mobile LiDAR Scanning, laser scanners mounted on a moving platform (vehicle, trolley), Airborne LiDAR (ALS) laser scanners mounted on

aircraft or drones (UAV-LiDAR), Handheld / Backpack LiDAR (SLAM-based LiDAR) Portable scanners using SLAM (Simultaneous Localization and Mapping) technology, Bathymetric LiDAR which uses green wavelength lasers to penetrate water (Maté-González et al., 2022).

1.3 Need for using Lidar technology:

A thorough assessment of the condition of historic structures is essential to understand their current state and identify risks that may affect their preservation. Regular monitoring over time enables the detection of deterioration trends and provides valuable insights for making informed conservation and management decisions.(Adamopoulos & Rinaudo, 2021).

1.4 Advantages of using Lidar technology:

3D documentation, multiscale database of monument and digital blueprinting of heritage structures provides the necessary details and information for constructing heritage inventories, assessing damages/ risk and management and monitoring the built heritage sites (Hina Pande, 2022)**.** Many studies have proved that terrestrial laser scanner is a powerful tool towards recording of objects and sites for heritage preservation purposes, scientific research and built environment applications (Hina Pande, 2022)**.** The documentation of cultural heritage using terrestrial laser scanning (TLS) technique has significantly increased (Remondino, and Campana, 2014). This fact is mainly due to the wide availability of laser scanning technology and its ability to provide dense surface models in a short period of time with accuracy and reliability. (Hina Pande, 2022)

1.5 Challenges in using Lidar technology:

Recently, however, public funding has been reduced, leading stakeholders and researchers to develop low- cost geomatic tools and methodologies, without compromising the metric accuracy.(Vacca, 2023) A systematic and targeted use of 3D surveying and modelling in the cultural heritage field is still not yet employed in India. Widespread practical application by users is lacking hence in order to utilise the technology for practical operational work, a set of standard operating procedures needs to be developed. This will enable easy understanding of the complex technique and instrumentation by non-experts. (Hina Pande, 2022)**.** Improper filtering and registration of point-cloud data can result in noise, misalignment and loss of detail, resulting in geometric distortions that compromise the accuracy and authenticity of 3D heritage documentation models. So for processing vast point cloud datasets demands specialized skills and powerful computing systems, making training and technical expertise crucial for accurate interpretation (Zhao et al., 2023)

1.6 Future use of the digital documentation of heritage structures:

Extraction of geometric information from LiDAR data in form of point cloud data can be converted into parametric modelling in form of Historical building information modeling (HBIM) for further structural analysis (Argiolas et al., 2019). Advanced digital technologies, such as 3D modelling, artificial intelligence, machine learning, cloud computing, virtual reality (VR) and augmented reality (AR), have driven an outstanding paradigm shift in the field of cultural heritage toward harmonized documentation and management, inclusive accessibility and fruition, as well as condition monitoring and preventive conservation (De Fino et al., 2023)

1.7 Aim, objectives of research:

This research aims to evaluation of LiDAR technology in Architectural Heritage Documentation. The objectives of research are to evaluate the application of LiDAR in selected heritage case studies such as Rani ki Vav and the Qutb Minar complex, to analyse user's perspectives on LiDAR, focusing on operational challenges, data processing limitations, cost implications, and technical skill requirements.

2 Methodology:

The research covers two layered methodologies with case study analysis and structured questionnaire-based survey to evaluate the application of LiDAR technology in architectural heritage documentation. The first component involves a detailed examination of case studies of two UNESCO World Heritage sites namely Rani ki Vav in Gujarat and the Qutb Minar Complex in New Delhi. These are analyzed using based on detailed architectural styles, method and type of LiDAR systems and application of LiDAR systems in heritage conservation. The second method comprises of a structured questionnaire-based survey method of conservation architects, researchers, Architects, engineers, students of architecture. Demographic data like age, number of years of experience of total 49 respondents were collected. The gap between familiarity, application and use of LiDAR technology were analyzed from user's view point. The major challenges in implementing the technology were also discussed.

2.1 Case study 1: Rani Ki Vav, Patan, Gujrat

Rani Ki Vav, Patan, Gujrat has UNESCO's World Heritage status. It was documented by Delegation from Centre for Digital Documentation and Visualization (CDDV) and Archeological Survey of India (ASI) in Oct 2010 using Lidar technology.

It was built around 1050 A.D. Apart from source of water supply for community it is also used for social gathering, religious rituals patronized by royal Queen Udayamati built it in memory of her husband King Bhimdev I (*Rani-Ki-Vav (the Queen's Stepwell) at Patan, Gujarat - Documents - UNESCO World Heritage Centre*, n.d.). Rani ki Vav is designed in inverted-temple style with seven-terraced stepwell descending almost 27m deep and 7m circular core extending vertically. Each terrace

contains pillared pavilions, sculptural panels, and stepped corridors leading towards the well shaft. The stepwell is adorned with around 400 numbers of sandstone sculptural panels of one-metre height depicting Vishnu's incarnations, mythic narratives, and water motifs like overflowing pots, reflecting its ritual link to the River Sarasvati.

Its documentation used multi-modal 3D scanning: Leica C10 for full geometry, Leica HDS6100 for high-resolution interiors, Artec structured light for sub-millimetre sculptural detail, along with HDR imaging and panoramic photo capture. Data was processed daily on-site, overcoming equipment overheating to produce an archival 500GB digital dataset supporting global preservation and conservation planning.

A combination of terrestrial and mobile LiDAR scanning was employed across 72 scanning positions, covering all seven levels of the monument. The LiDAR system achieved a precision of 1.5 cm, enabling a detailed 3D digital model. The project demonstrated LiDAR's unmatched ability to record inaccessible spaces accurately and provided crucial insights for ongoing conservation and restoration work at this historic site. (Plant et al., 2012)



Figure 1: View of Rani Ki Vav, Gujrat



Figure 2: Rani ki Vav – documentation on site by LIDAR

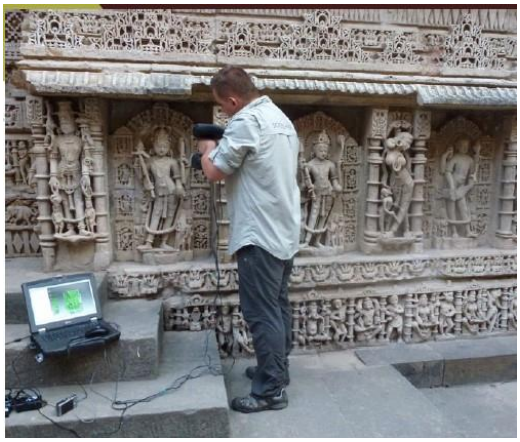


Figure 3: Detailed documentation of Sculptures of Rani ki vav using LIDAR Technology

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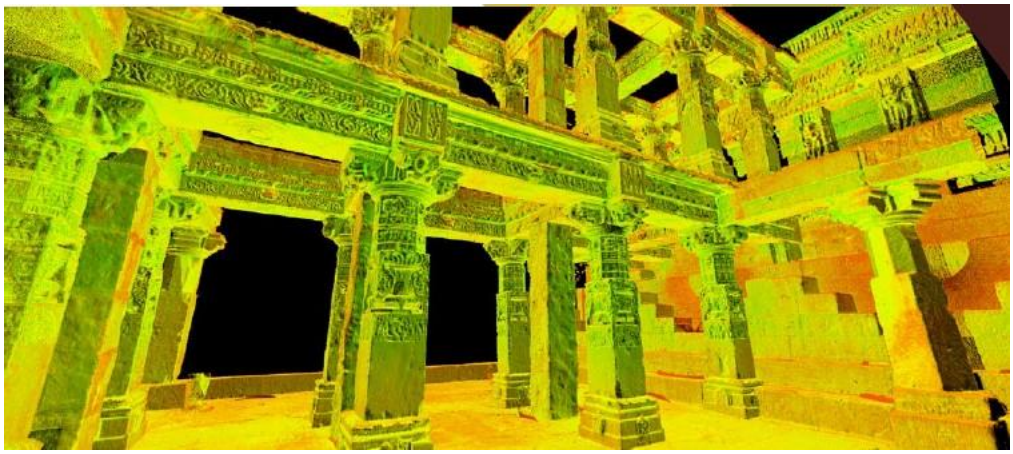


Figure 4: LiDAR data registration showing pillared pavilions near the entrance wall.
Source 1,2,3,4: LIDAR -VOL2- ISSUE 1- Heritage Documentation

2.2 Case study 2: The Qutb Minar complex, Delhi.

The Qutb Minar complex has UNESCO world heritage status and is situated on the south of New Delhi, comprising mosques, minars, and related monuments, during the 12th century by early Islamic rulers after establishing their authority in the Indian subcontinent. The purpose of the complex is to exhibit Islamic rulers' ambition to reshape the region from Dar-al-Harb (Land of war-where Islamic rule is not there) to Dar-al-Islam (Land of Islam where Islamic rule is practiced) by introducing unique architectural forms and typologies.

Each mosque has typical elements like Sahn (Courtyard), Hypostyle Prayer Hall-roofed Hall with columns for prayers, Mihrab- Niche indicating qibla (direction of Mecca), Qibla Wall- wall facing Mecca, Minaret (Minar)- Tower used for the call to prayer, Iwan / Arches- Monumental arched openings. Qutb Minar minaret was missing component in the Quwwat-ul-Islam Mosque complex which was completed between 1199 and 1503. It is erected at the south-eastern corner of the mosque reflect the architectural style of Ghurid homeland of the rulers. The height of Qutb Minar rises to 72.5 meters, tapering from base diameter of 14.32 meters to 2.75 meters at the peak. It is constructed in red and buff sandstone with carved inscriptional horizontal bands depicting Hindu temple style architecture. Vertical grooves or fluting are also observed on column with alternate profiles of angular and rounded grooves giving visual rhythm, textural richness and dynamic light and shadow patterns which is hallmark of Ghurid architectural style (*Qutb Minar and Its Monuments, Delhi - UNESCO World Heritage Centre*, n.d.)

The case example of the Qutub Complex (Delhi) displays variety and complexity of structure e.g. a vertical tapering tower with considerable height, extensively damaged structures and wide expanse of the site.

Procedural workflow for Lidar scanning

1. **Data acquisition, Integration and Generation of 3D model:**

First the overall form of the structures was defined, then of multiple high-overlap scans (90%) were acquired to ensure precise capture of architectural details and carvings.

The terrestrial laser scanning (TLS) -derived point clouds were then refined through filtering, and each scan was co-registered to create a unified 3D dataset. Point clouds from all scan positions were subsequently merged and aligned to produce the final consolidated 3D point cloud model of the site.

2. **Extraction of Architectural Elements and Digital Blue Printing:**

Architectural elements were identified by smoothing and edge extraction from the coloured point cloud. Image-based algorithms refined the primary boundaries, but fine detailing required manual adjustment to accurately represent the elements.

The same process was repeated for other parts of the point cloud to extract different architectural features automatically. Once each element was captured, they were brought together to create a complete digital blueprint of the monument.

Such 3D digital heritage documentation by LiDAR enables the non-invasive structural assessment, Damage detection and virtual repair, reconstruction of missing elements creation of digital museums and virtual environments. (Hina Pande, 2022)



Figure 5: Qutub complex, Delhi



Figure 6: Qutub Minar showing horizontal carvings and vertical alternate angular and rounded grooves or flutings.

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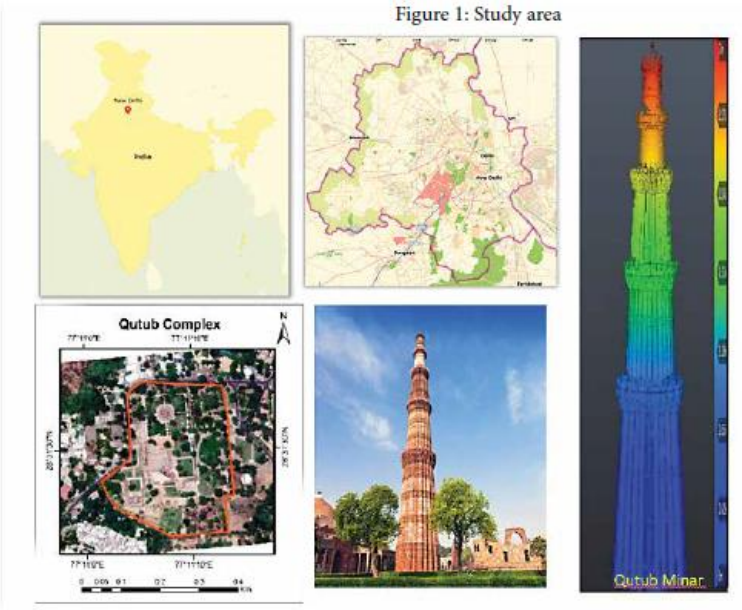


Figure 7: Data processing and integration a) Far range point cloud, b) Near range point cloud, c) Integrated point cloud, d) Point cloud depicting height

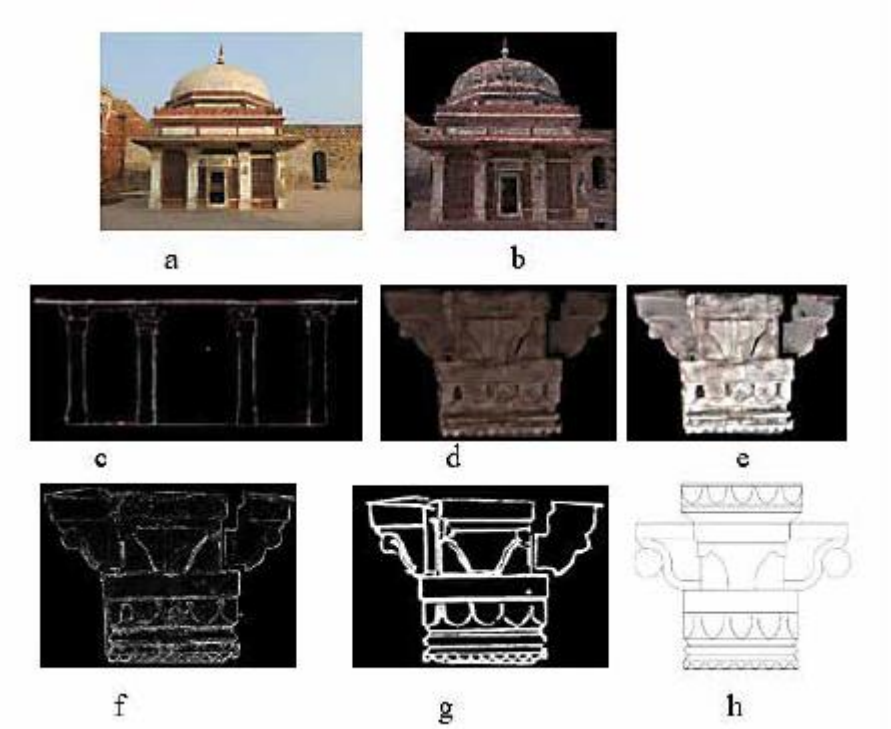


Figure 8: Extraction and refinement of architectural elements. **a)** Tomb of Imam Zamin, **b)** Textured point cloud, **c)** Extracted pillars, **d)** Original point cloud for part of pillar **e)** smoothed point cloud **f)** extracted edges **g)** edge refinement with active contours **h)** after manual refinement and editing.

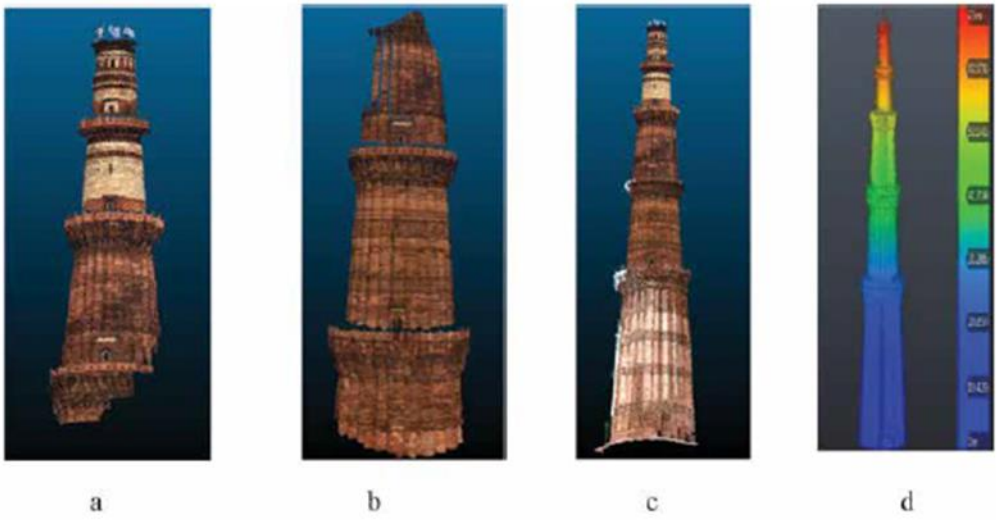


Figure 9: Data processing and Integration a-b: individual point clouds from different locations, c: Integrated Point cloud, d: Coloured point cloud depicting height variation.

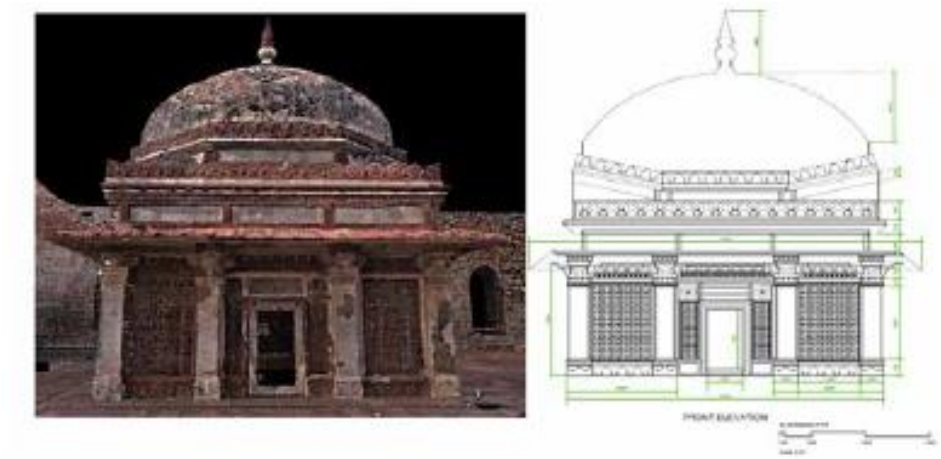


Figure 10: Laser scan derived blue print for Tomb of Imam Zamin, Qutub Complex.

2.3 User based evaluation of application of LiDAR technology in architectural heritage documentation.

A structured questionnaire-based survey was conducted to understand the perceptions, competence levels, and challenges associated with LiDAR technology in architectural heritage documentation. Sampling approach is purposive sampling of 48 respondents with target group of individuals engaged in heritage documentation and digital documentation studies was taken. Data collection tool used is online questionnaire survey with closed-ended questions with help of Google Form was conducted.

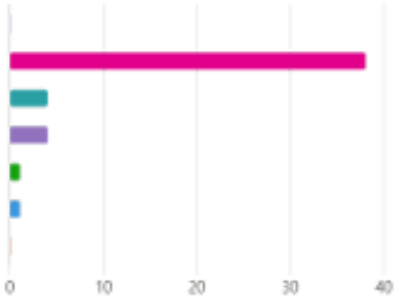
1. What is your gender?

Woman	42
Man	6
Non-binary	0
Prefer not to say	0



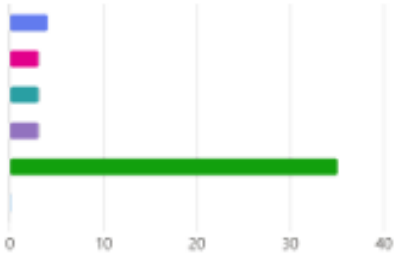
2. How old are you?

< 18	0
18 - 25	38
26 - 35	4
36 - 45	4
46 - 55	1
> 55	1
Prefer not to say	0



3. Professional Background:

Architect	4
Conservation Expert	3
Researcher	3
Engineer	3
Student	35
Other	0



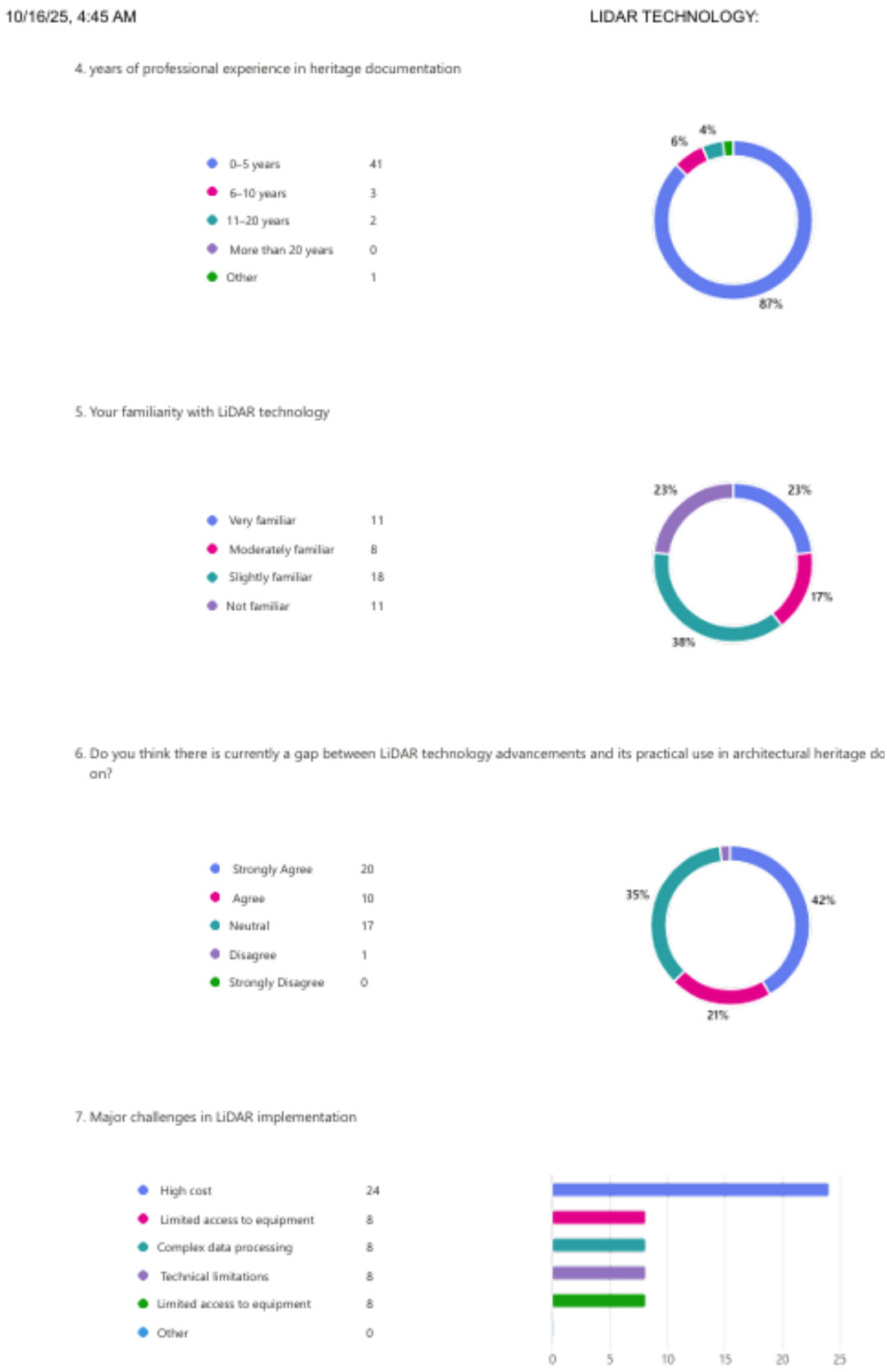


Figure 11: Questionnaire

3 Data Analysis

3.1 Analysis of Case study-based method:

Rani Ki Vav, a UNESCO-listed 11th-century stepwell in Patan, Gujarat, represents an exceptional example of subterranean temple architecture. The high-resolution digital record enabled precise mapping of erosion, surface loss, salt deposits, and structural displacement, proving essential for conservation diagnostics. LiDAR further permitted visualization of inaccessible niches, narrative friezes, and deep carved recesses that are difficult to document through conventional photography. The resulting dataset supports virtual reconstruction, digital museum experiences, and long-term preservation planning of this unique stepwell heritage. combining hydraulic engineering and sacred spatial symbolism.

For The Qutb Minar complex, Delhi Terrestrial Laser Scanning (TLS) with phase-based LiDAR scanner was used to record fine ornamentation and surface variation. Multiple scan stations (with 90% overlap) ensured robust registration and reduced geometric drift. LiDAR-derived coloured point clouds supported differential extraction of architectural layers.

3.2 Analysis of questionnaire survey-based method:

Survey responses were analyzed using google form generated statistical analysis through descriptive statistics of frequency and percentage. Further the result was represented through bar graphs and pie charts.

The demographic analysis shows participation by early professionals. Professional background suggests that LiDAR awareness is currently more concentrated in academic exposure than in professional application. Experience in Heritage documentation with large presentation of beginners reflects a growing but still nascent technical exposure to digital heritage documentation. Familiarity with LiDAR Technology shows that while LiDAR is recognized, competency remains limited. Only 40% claimed moderate to high familiarity. A significant 63% believe that there exists a gap between LiDAR advancements and its practical application in heritage conservation. High neutrality indicates uncertainty driven by low hands-on exposure. Cost and access barriers are the primary impediments, processing complexity and technical limitations indicate a systemic training gap rather than lack of interest.

4 Conclusion:

- The LiDAR documentation of Rani Ki Vav establishes a benchmark in non-invasive heritage recording for complex subterranean architectural environments. The seven-tiered, 27-metre-deep stepwell, containing nearly 400 sculptural panels, features tightly carved surfaces and narrow passageways that make conventional surveying difficult. Its complex geometry, vertical depth, and confined spatial layout create documentation challenges that traditional recording techniques cannot capture with the required level of precision.
- The Qutb Minar case demonstrates LiDAR's transformative role in documenting complex Indo-Islamic geometries and monumental Islamic verticality. Its hybrid architectural language Ghurid minar typology overlaid with temple-craft carving was captured with unprecedented clarity, creating a conservation dataset that supports future restoration, academic research and heritage-experience digitisation. LiDAR thus establishes a scientific, replicable, and ethically non-intrusive foundation for safeguarding one of India's most historically layered monuments.
- The survey results demonstrate that while LiDAR technology is widely acknowledged as a promising tool for heritage documentation, its integration into professional practice remains limited. Respondents, largely students and early-career practitioners, showed theoretical awareness but minimal hands-on exposure, indicating a developmental stage of adoption within the conservation field. High equipment cost, restricted access to scanners, and complex data processing workflows continue to act as major deterrents. These factors collectively contribute to the gap between technological advancement and its practical on-site application.
- Thus, LiDAR proves highly effective for documenting complex heritage forms like Rani Ki Vav and Qutb Minar, capturing details unreachable by traditional methods. While its precision and non-invasive recording benefit conservation, real-world adoption remains limited due to high costs, restricted access, and technical skill requirements.

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Architect's Interpretation and Application of Vastushastra in Residential Buildings

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Abstract - In contemporary residential architecture, Vastu Shastra continues to influence design decisions, driven by client expectations mainly because of their rooted cultural beliefs. Regardless of technological advancements and changing today's urban lifestyles, its principles remain integral part of key design decisions such as entrance orientation, kitchen layout, pooja room placement, master bedroom position and overall site planning. Vastu's relevance is not only found in its spiritual roots but also in its practical understanding which emphasizes harmony with natural light, ventilation and movement of energy within a space. As a result, Vastu Shastra acts as a bridge, enduring wisdom of the past with the creativity and demands of contemporary architectural design.

This study uses a questionnaire survey directed at practicing architects to collect data. The survey focuses on – Architects' acquaintance and beliefs about Vastu Shastra, the key design

elements for residential space are influenced by its principles, usually who initiates Vastu related requirements in projects and it also explores the challenges faced by architects when incorporating Vastu principles into modern residential architecture.

This approach provides structured quantitative data, providing practical insights, application and interpretation of Vastu in contemporary architectural design.

Based on the questionnaire, findings show varying levels of familiarity with Vastu Shastra among architects, with many indicating that Vastu requirements are primarily driven by clients rather than initiated by architects themselves. Residential spaces which are most likely to be influenced by Vastu principles are entrance orientation, master bedroom position, kitchen layout and pooja room placement. While beliefs in the spiritual and religious aspects of Vastu differ.

According to survey respondents, these findings illustrate how architects successfully achieve a balance between traditional Vastu principles and the requirements of modern design. Consequently, Vastu Shastra remains a relevant and flexible manual for contemporary residential architecture.

Keywords- Vastushastra; spatial organization; client influence; architects' interpretation; design considerations

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1. Introduction

Vastushastra, an ancient architectural science, with origins tracing back over 5000 years, has evolved in conjunction with Indian civilization, grounded in a profound comprehension of the physical realm and elements of nature. Foundational texts like Vastushastra and Manasara establish its philosophy and practice, highlighting the interconnectedness between architecture, nature and cosmic energy. (Understanding the Science of Vastu Shastra, 2025)

The key principles of Vastu Shastra includes :- Spatial arrangements & ideal proportions, incorporation of natural elements and materials and energy flow & harmony through directional alignments.

The key idea of these principles is a balanced life and work environment, which is achieved by aligning with natural forces and cosmic energies. (Scientific Vastu Shastra Core Principles and Applications, n.d.) Based on the knowledge of the movements of the sun and earth's magnetic field, among other things, the principles of Vastu Shastra can be applied to any home and make it an ideal dwelling. (Vastu Shastra for Flats and Apartments, 2023)

Vastu Shastra, recognizes the influence of the five elements - Earth, Water, Fire, Air, and Space - on the energy flow within habitable spaces. These elements are the foundation of Vastu Shastra and play a vital role in creating balanced and harmonious environment. (Five Elements in Vastu Shastra: Their Importance & Applications, 2023)

These elements are closely linked to natural forces which shape the environment. These natural forces are solar radiation, magnetic field, gravitational force, air currents, etc.,

By aligning architectural forms with these forces, it reduces stress, enhance mental clarity and ensures balanced energy distribution. (The Importance of Vastu: Explained in a Scientific Way, n.d.)

However, the idea of Vastu shastra and its relevance is a matter of individual and cultural beliefs of an individual too. It depends on the individual, group or organization to incorporate the principle of Vastu shastra in architectural design. (Relevance of Vastu Shastra in Architecture, 2023)With urbanization and rapid advancements in technology, modern homes often lack a connection with nature. Vastu Shastra bridges this gap by promoting designs that harmonize with natural forces. (Importance of Vastu Shastra in Modern Home Construction, 2025)

The application of Vastu Shastra in urban housing highlights not only cultural continuity but also practical benefits like improved daylighting, airflow, and stress reduction. (TIMESOFINDIA, 2023)

Vastu Shastra in modern architecture is not just a trend but the architects are advertising it as a key highlight of the residential and commercial place. This implementation allows for precise planning and execution, ensuring that the final design meets both modern standards and traditional beliefs. In this way, Vastu Shastra in modern architecture is creating a bridge between ancient wisdom and contemporary technology. (Residences, n.d.)

Vastu appears to have a bright future in real estate development. Developers will probably discover creative methods to integrate these ideas. While Vastu Shastra was traditionally

applied to single-family homes, its principles can still be considered when living in a high-rise apartment. Having a home that follows these principles is very important to people who have a deep connection to Vastu. Broader spectrum of customers find Vastu-compliant buildings appealing. This can attract a premium price point in addition to increasing sales potential. (Property, 2024)

2. Literature review

2.1 Vastu

Vastu Shastra came into the existence during the Vedic period and it deals with the design, construction techniques, and management. Vastu Shastra is the consequence of the Indian culture, religion, and natural phenomena which is responsible for the well beings of the human. (I.CV.Sagar, 2021)

Vastu-Shastra concentrates deeply more on how to receive the best utilization from the surrounding environment by correct positioning of rooms (for specific purpose) also in addition to the positioning of the whole building. The vastu-shastra insists the principles of positioning of inner rooms, the ground and the building. This elaborates the relationship between the man and his physical body, the building and the world. Hence this go beyond Design and Architecture. (S. Suriyanarayanan, 2016)

It has been observed and proved by many sages and modern architects that the structures which are planned and constructed according to Vaastu principles are more auspicious in which positive energy synergizes with mental, metaphysical & functional well – being and happiness of inhabitants. (Aman Kumar Gupta, 2020)

2.2 Core principles of vastushastra

Vastu is not a religion it's a science of setting the things rightly and balances the five elements of nature which are earth, fire, water, space and air. (BARODIA)

Vastu principles have evolved over time, incorporating traditional building materials, local construction techniques, and architectural details that adapt to local conditions, including local climate and available materials. (Rana, 2025)

The basic principles of Vastushastra are rooted in site orientation, planning, proportion, dimension, and aesthetics to ensure harmony between the built form and natural forces. These guidelines such as –

1. The *Vastu Purusha Mandala* for site planning
2. *Maana* for proportions,
3. *Aayadi* for dimensions
4. *Chanda* for aesthetics

Provide logical and scientific methods for creating balanced and functional buildings. Together, they serve as a framework for designing spaces which are proportionate, environmentally aligned, and meaningful. (SHARMA)

2.3 User/client/real estate demand

Purchase a residential property is a high-involvement decision and because of that buyer goes through a complex decision-making process. In this complex process, the buyer goes for extensive search for information from various sources. (Yogesh Kumar, 2018)

Comfort in any built environment can be assessed through many different criteria; some of these aspects are measurable through quantitative methods, some are qualitative and are expressed through feelings and others are ineffable such as the users' personal choices. (KARANI, 2019)

The buyer preferences are studied mainly to understand the housing structure coupled with facilities as offered by developers and desired by the customers. The variables covered in the study are type of housing prospective customers want to purchase, size of house/apartment they are looking for, size of the property, their budget, possession date, primary criterion to meet while purchasing the residential property, vaastu , puja room and servant room preferences, preference in style of kitchen, balcony usage purpose, flooring preference, window preference, amenities preference, maintenance payment preference, views on residential properties being sold online, preference in smart homes and green buildings. (Sharma, 2022)

2.4 Contemporary practice

Today the practice of Vaastu Shastra is highly fragmented beyond recognition. Vastushastra principles often used in isolated form rather than being applied as comprehensive model, which contribute in shaping the language for overall contemporary residential architecture (Patra, A Comparative Study on Vaastu Shastra and Heidegger's 'Building, Dwelling and Thinking, 2006)

The integration of traditional architectural knowledge, such as Vastu Shastra, into modern architectural practice faces several challenges. A key issue is the difficulty in reconciling traditional methods with contemporary building technologies, which often leads to a struggle between ancient wisdom and modern design requirements. (Ar. Shaheen Sobti, 2025)

Vaastu Shastra and contemporary construction methods are compared to identify similarities and differences in a number of important areas, including site analysis and selection, orientation determination, site planning, proportional building measurements, dimensions, aesthetic considerations, zoning regulations, and door placements. (Deepti Pande Rana, 2025)

2.5 Applications in housing

Vaastushastra stipulates that specific functions of the house should be located in specific corners of house, the explanation behind this is that the function matches the element that is located in that corner. The approach to spread the functions in the house this way could be understood as an adaptive approach to designing the space. (Karani, 2024)

Housing has been acknowledged as a basic need of all human beings. Apart from three basic needs – food and clothing, shelter is a basic instinct of human. House is constructed by people not only for their housing requirements but it holds significant societal value and also considered as a symbol of credibility. Housing is vital catalyst for transformation of housing society. (Parthiban, 2021)

Vaastu Shastra has evolved as a compilation of planning principles for a healthy living based on the knowledge base of the time. (Patra, Vaastu Shastra: Towards Sustainable Development, 2008)

3. Methodology

The data was collected through online questionnaire survey of practicing Architects. The total sample size obtained was 22. The research adopted a Mixed-Method approach to collect and analyze data. Data was collected using questionnaire containing both quantitative and qualitative components. The quantitative component includes close-ended questions like MCQs (single & multiple response), Rating scale questions (likert scale), Ranking questions (preferences), which used to identify patterns. The qualitative component includes open-ended questions focuses on understanding human experiences, insights and perceptions. The survey aimed to understand interpretation and application of Vastushastra principles and how they incorporate in the design. The study seeks to provide practical guidelines for designing residential buildings that are both functionally efficient and aligned with Vastu principles, ensuring human comfort. The questionnaire survey designed to collect data related to following variables -

1. Beliefs in Vastushastra
2. Use of Vastu principles
3. Most applied principles
4. Influence of Client/Builder
5. Impact on Architectural practice

4. Findings and analysis

4.1 Use of Vastu principles

This demonstrates that majority of Architects apply Vastu principles at **PLANNING STAGE**. On the basis of data received, we can say that Vastushastra is mostly used as a tool for spatial organization, which guides placement & orientation of rooms, circulation ,etc.,

Some Architects try to incorporate Vastu principles from the **CONCEPT DESIGN STAGE**, indicating blend of traditional principles with the initial design vision.

Just a small fraction of Architects takes Vastu into account at **SITE SELECTION STAGE**, showing it as less influencing factor in most of the projects.

As no responses were recorded for **EXECUTION STAGE**, it shows Vastushastra is primarily Planning & Design concept consideration & not a site correction tool.

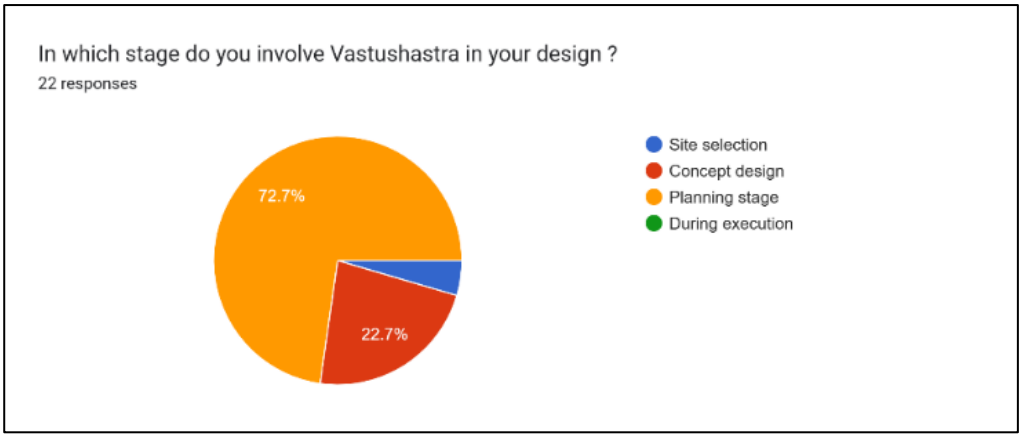


Figure 1. Integration at design

4.1 Most applied principles

Analysis based on the responses received is –

Particularly spaces like Kitchen, Master Bedroom, Entrance and Puja room are mostly considered for application of Vastushastra principles.

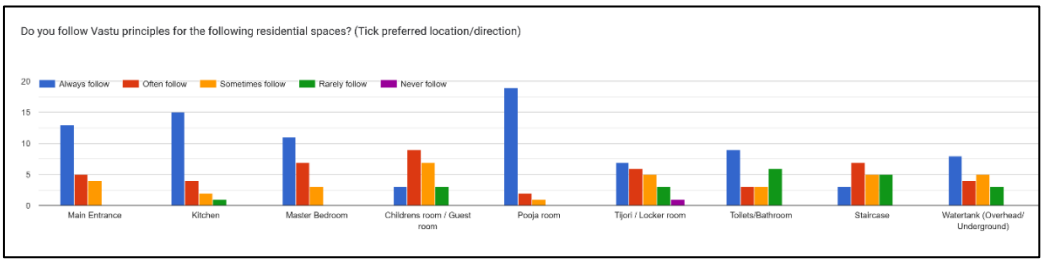


Figure 2. Vastu Compliance

KITCHEN – SOUTHEAST

MASTER BEDROOM – SOUTHWEST

ENTRANCE ORIENTATION & POSITION OF POOJA ROOM is emphasized considering they are prioritized by Architects/Clients.

Spaces which are taken into account which have a direct impact on daily life, wellbeing and comfort.

4.2 INFLUENCE OF CLIENT/BUILDER –

Client/Builder preferences have to be considered, because 59% of the Architects reported that they have to modify design to meet the requirement of Vastushastra principles in project. Highlighting adherence to these principles is often essential and not as optional.

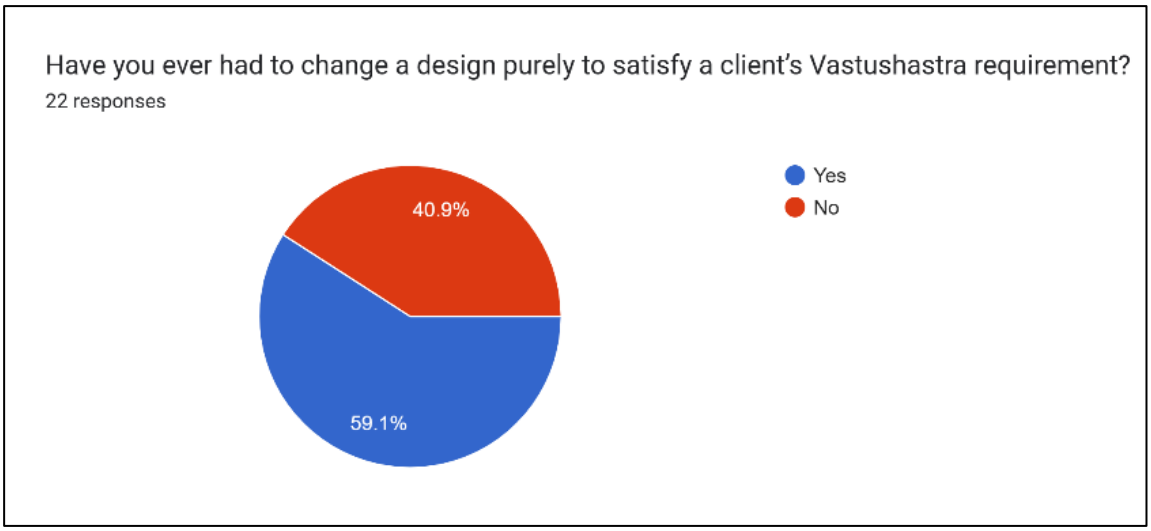


Figure 3. Design changes for Vastushastra

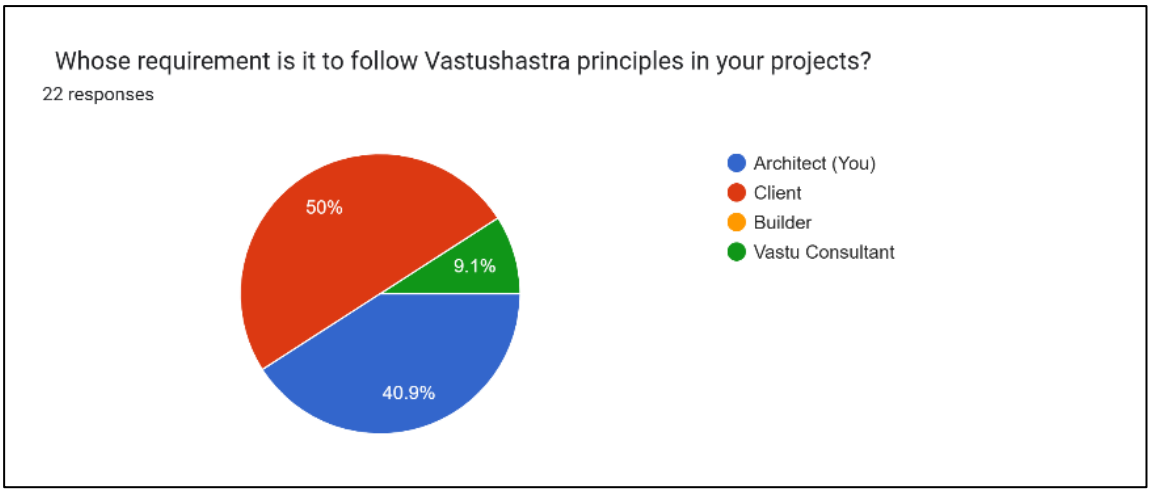


Figure 4. Impact on design adjustments

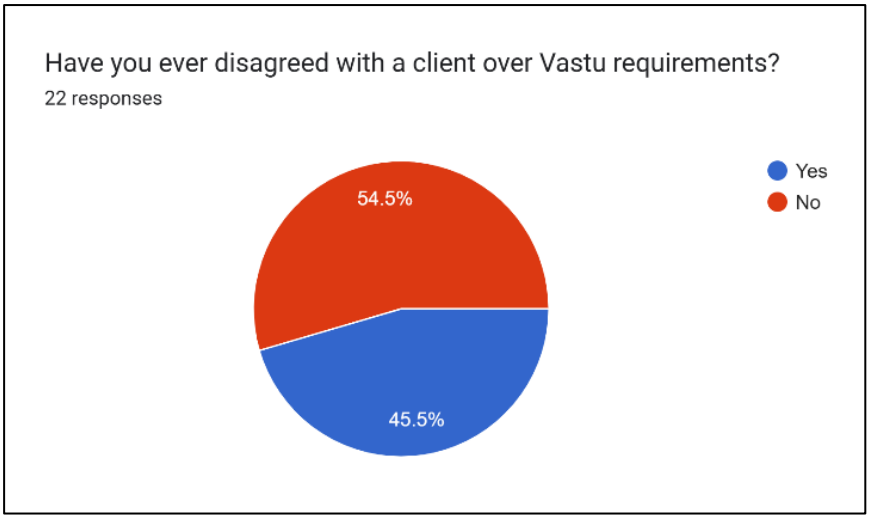


Figure 5. Vastu consultation

4.3 Impact on architectural practice –

Vastu is used in practical way rather than being followed strictly. But Vastu considerations often influences design because of client's preferences, sometimes leading to conflicts with functionality. Certain principles can complement functional design; however strict adherence could be challenging in large-scale residential projects.

Design solutions are adjusted to satisfy both preferences and functionality.

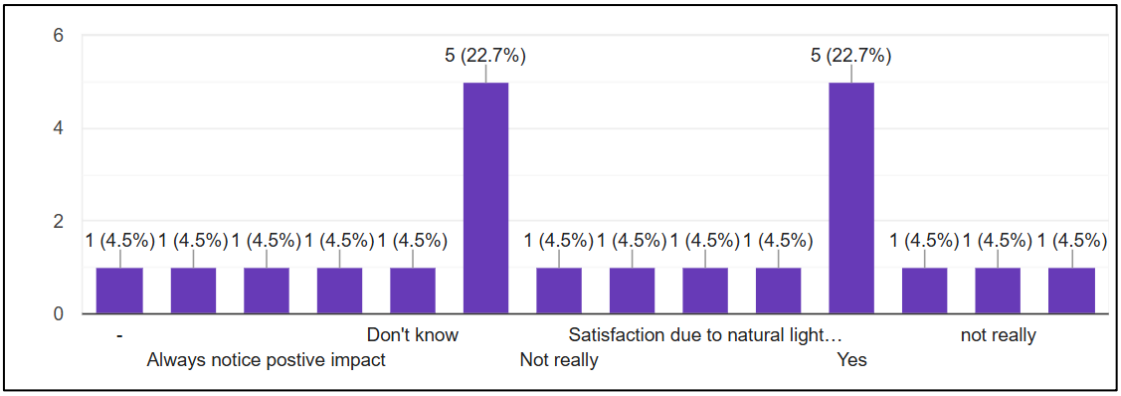


Figure 6. Vastu impact perception

Some architects noticed positive impact of Vastushastra, while others reported no observable impact.

A portion of respondents (22.7%) shows that Vastu contributes to satisfaction due to factors like natural light and ventilation. An equal percentage (22.7%) showing that many architects are unsure about the tangible benefits of Vastushastra.

5. Discussion & conclusion

This research explored how architects perceive, understand and apply that knowledge of Vastu Shastra principles in residential design, examining both knowledge and practical implementation. Residential projects are complex which demands a balance among, client preferences, functionality, environmental considerations and aesthetics of that particular space. Architects coordinate these client's demands while selectively incorporating Vastu principles, prioritizing those that enhance natural light, ventilation, orientation, and spatial harmony. Spaces which are taken into account which have a direct impact on daily life, wellbeing and comfort. Particularly spaces like Kitchen, Master Bedroom, Entrance and Puja room are mostly considered for application of Vastushastra principles.

KITCHEN – SOUTHEAST
MASTER BEDROOM – SOUTHWEST
ENTRANCE ORIENTATION & POSITION OF POOJA ROOM is emphasized considering they are prioritized by Architects/Clients.

As Architects are acting as mediators who can interpret traditional Vastu knowledge into practical solutions which also responds to modern lifestyle needs. Architects often have to face the challenge of balancing these factors along with including Vastu principles, which may create conflict with modern space requirements.

This interpretative approach ensures that Vastu is incorporated thoughtfully and not as rigidly, harmonizing both functional effectiveness and cultural essence. Crucially, by adapting interpretative approach, it enables architects to integrate Vastu thoughtfully, ensuring cultural essence, functional efficiency, visual appearance and human comfort. In conclusion, the study emphasizes considered application of Vastushastra empowers to create residential spaces that are context sensitive, innovative and also aligned with both traditional and modern lifestyle. Thereby, enhancing overall user satisfaction and spatial quality.

Conflict of interest: The authors declare no conflict of interest.

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TRACK 02
NEW TECHNOLOGIES FOR RESILIENCE



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Feasibility Study of Artificial Intelligence Driven Sustainable Building Optimization for a Resilient Built Environment.

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Abstract: The built environment increasingly demands innovative solutions that integrate sustainability, adaptability, and efficiency. The construction sector is evolving with addition of new digital tools like Artificial Intelligence (AI). AI is helpful in reshaping approaches to design, construction and operations. AI is proving to be a powerful enabler in optimizing building performance across the lifecycle, driving climate responsive and resource efficient outcomes. The study conducts a feasibility assessment of AI-driven sustainable building optimization as a strategic pathway towards resilience in the built environment. The research framework assesses environmental, technical, operational, and economic feasibility measuring possible reductions in energy consumption, carbon footprint and resource wastage. Early findings suggest that AI- enabled optimization can achieve 15- 25% energy savings while also fostering adaptability and advancing innovation sustainable design practices. The research also identifies critical conditions for successful implementation. Reliable data sets, human collaboration, and strong ethical and governance frameworks are essential for effective and responsible application. The findings of the feasibility study will guide architects, consultants and policy makers in making informed decisions in embedding Artificial Intelligence as a digital tool for sustainable and resilient building strategies, bridging the gap between technological innovation and proven practices in India's evolving urban and rural landscape.

Keywords: Sustainable Buildings; Artificial Intelligence; Resilient Built environment; Design optimization.

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1. Introduction

The construction industry is undergoing a significant transformation, propelled by the integration of Artificial Intelligence (AI) which aim to advance sustainability, resource efficiency and resilience within the built environment. As global concerns over climate change, energy consumption intensify, integrating Ai into sustainable construction practices presents both opportunities and challenges. The built environment which constitutes for nearly 40% of global energy consumption and one third of greenhouse gas emissions, needs a transformative shift that goes beyond green building design. (Adewale, 2024) As cities expand an infrastructure ages, the need for sustainable and resilient building, those capable of minimizing environmental impacts while adapting to future uncertainties—has become central to architectural and construction practices.

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Resilience in the built environment refers to the capacity of buildings and infrastructure to withstand, recover, and adapt to environmental, economic, and social disruptions such as climate hazards or resource scarcity. Sustainability, on the other hand, emphasizes long-term ecological balance through efficient resource utilization, waste reduction, and carbon-neutral operations. Collectively, resilience and sustainability represent the foundation of next-generation construction practices.

Within this context, Artificial Intelligence (AI) is emerging as a transformative digital tool. It is revolutionizing building design, performance optimization, and operational efficiency (Chen et al., 2024). Artificial Intelligence (AI) can make buildings smarter and more sustainable by using advanced computer systems that learn from data. Data Analytics helps collect and study information about how a building uses energy. Machine learning (ML) is a part of AI that allows computers to learn patterns and make predictions without being directly programmed. Predictive Modelling uses this information to forecast things like future energy needs or maintenance issues. When AI is combined with Building Information Modelling (BIM), a digital 3D model of a building and Internet of things (IOT) sensors, which track real-time data such as temperature or air quality, it can help manage energy systems more effectively and support greener, more efficient buildings.

This paper investigates the feasibility of AI driven sustainable building optimization providing a strategic pathway to resilience in the built environment. By conducting a qualitative feasibility assessment based on secondary data, this study aims to guide architects, consultants, and policymakers on **integrating AI into sustainable building strategies** to foster a resilient built environment. The study systematically reviews secondary data to assess how AI technologies contribute to sustainability objectives, including energy efficiency, resource conservation, and lifecycle resilience. It also identifies **technical, economic, environmental, social, and policy feasibility** influencing adoption and evaluates the **challenges and opportunities** inherent to AI integration in the built environment.

2. Literature Review

2.1 Artificial Intelligence in the Built Environment

Artificial Intelligence (AI) is increasingly influencing how buildings are designed, constructed, and managed, mainly by using data analysis and automation to make decisions that were once based on experience or intuition. Its integration into architecture, engineering, and construction (AEC) has accelerated using data analytics, pattern recognition, and networked sensing technologies that enable intelligent decision-making and adaptive control. By analyzing the large amount of data produced throughout the building process, these technologies help in making better choices about energy use, structure, and material performance. (Ajayi et al., 2024).

A key application of AI lies in **building performance prediction and control systems.** Studies by (Tosin Daniel Iluyomade, 2024) and (Bhardwaj, 2025) show that **AI-enabled energy management systems** can optimize HVAC performance and lighting control, reducing energy consumption by up to 25%. **Digital twin models** further enhance predictive maintenance by continuously analyzing sensor data to identify performance gaps and irregularities within building operations (Ibrahim Elwy, 2024). Reinforcement learning helps systems learn from experience, making facility management more proactive than reactive

Architectural workflows are being transformed through computational generative design, which produces adaptive, climate-responsive solutions that enhance spatial functionality. (Feyisayo Ajayi, 2024). Integrating AI with BIM fosters the creation of predictive and performance-based models that evaluate environmental responses, construction workflows, and sustainable design outcomes, advancing the goal of a more resilient and adaptive built environment. (Chinwe Emedo, 2025). Together, these advancements mark a move away from fixed design approaches toward more flexible systems that can adjust to changing environmental and operational conditions.

2.2 Sustainable Building Optimization

The growing demand for sustainable construction is driven by global environmental challenges, particularly the urgency to mitigate greenhouse gas emissions and achieve net-zero energy targets. Artificial Intelligence (AI) plays a pivotal role in this transition by supporting energy modeling, resource optimization, and life-cycle assessment (Piragash Manmatharasan, 2025). Through advanced simulations, AI enables architects and engineers to evaluate design alternatives for improved energy performance, daylight optimization, and material efficiency

Empirical studies demonstrate that AI based predictive analytics can significantly enhance the operational efficiency of HVAC systems, achieving potential energy savings of 15–30% (Saif Mohammed Ali, 2025). In parallel, the emergence of smart materials such as self-healing concrete, phase-change materials (PCMs), and carbon-fiber composites further contributes to sustainability by enabling self-regulation and extending material lifespan (Taher Mohammed Taher Alghusni, 2025). AI technologies complement these advancements by predicting material degradation, scheduling maintenance activities, and optimizing material consumption, collectively reducing construction waste by 20–25%. Another promising development lies in AI-assisted energy generation and storage optimization. Machine learning algorithms are employed to forecast renewable energy availability, optimize grid interactions, and balance energy demand and supply. This integration enables buildings to function as micro-energy hubs, enhancing both sustainability and resilience.

2.3 Resilient Built Environment

Within the built environment, resilience transcends traditional sustainability goals by emphasizing the capacity of structures and systems to anticipate, withstand, and adapt to disturbances arising from climatic, environmental, or socio-economic challenges. AI contributes to resilience through **risk prediction, real-time monitoring,** and **adaptive design frameworks** (Jinyi Li, 2024). Predictive analytics uses weather and building performance data to spot weaknesses early and suggest ways to prevent damage. AI

simulations can test how structures respond to disasters, helping engineers design safer and more adaptable buildings (Associates, 2025). Similarly, **AI integrated urban planning tools** enable cities to model environmental stressors like heat islands, flooding, or energy disruptions and design responsive infrastructures. The combination of **AI, BIM, and City Information Modeling (CIM)** forms the foundation of **resilient smart cities**, where real-time data is used for efficient resource management, disaster preparedness, and infrastructure maintenance (Jinyi Li, 2024).

2.4 Review of Existing Studies and Identified Research Gap

Research shows that AI can greatly improve sustainability in the built environment, but most studies focus mainly on energy use and system performance, giving less attention to long-term resilience and social or economic practicality. (Eashwaraj, 2025). While successful models such as Singapore's Smart Nation and Masdar City demonstrate AI's capacity to enhance resource efficiency and environmental performance, their replication in developing economies remains challenging due to cost, data, and infrastructure limitations. Adoption of AI technologies is also constrained by issues such as inconsistent data management, limited professional capacity, and underdeveloped policy and regulatory support. (Bura, 2025). Concerns about fairness, privacy, and transparency in AI tools are becoming important issues for sustainable design. (Adewale, 2024)

Despite growing interest in AI applications, the literature lacks a comprehensive evaluative model that integrates sustainability, resilience, and ethical dimensions. Studies to date tend to assess isolated performance indicators rather than examining the wider technical, economic, and policy implications of AI integration, with limited attention to the Indian built environment. To address this research gap, the study conducts a comprehensive feasibility assessment encompassing environmental, technical, economic, and governance dimensions, aiming to link technological innovation with its practical realization in fostering resilient and inclusive urban futures.

3. Methodology

This study adopts a **qualitative feasibility research design** based primarily on secondary data, literature synthesis, and comparative global case studies analysis. The goal is to evaluate the **technical, economic, environmental, social, and policy feasibility** of AI driven optimization in sustainable and resilient building systems. As emerging digital technologies evolve rapidly, secondary research provides a comprehensive, evidence-based means to evaluate adoption readiness without the constraints of primary data collection

3.1 Research Approach

The study adopts an analytical framework to examine global and regional cases of AI integration in sustainable building design and operation. A systematic review of academic and industry sources informs the analysis, which evaluates AI-driven

optimization across five feasibility dimensions: environmental, technical, economic, governance, and social resilience.

- **3.1.1 Technical feasibility**: Evaluating the reliability and maturity of AI tools, data availability, interoperability, and system integration.
- **3.1.2 Economic feasibility**: Analyzing capital investment requirements, potential operational savings, and overall market readiness.
- **3.1.3 Environmental feasibility**: Measuring reductions in energy consumption, carbon emissions, and material waste.
- **3.1.4 Social feasibility**: Examining user acceptance, skill adaptability, and ethical accountability associated with AI adoption.
- **3.1.5 Policy and governance feasibility:** Reviewing institutional support mechanisms, regulatory standards, and policy frameworks facilitating AI implementation in sustainable construction.

3.2 Data Collection and Evaluation

Data were sourced from secondary materials, including academic publications, international and national case studies, and established sustainability assessment frameworks. Each study was evaluated for indicators of success, implementation barriers, and performance outcomes. This approach enables comprehensive exploration of technical, environmental, and ethical dimensions, ensuring reliability and validity through synthesis of verified empirical evidence.

4. Comparative Case Study Analysis

Table 1. *Feasibility Comparison of 4 AI-Driven Sustainable Building Projects across the world.*

Feasibility Dimension	The Edge, Amsterdam	Infosys Campus, Nagpur	22 Bishopsgate, London	Shanghai Tower, China
Project Type	Commercial office	Corporate campus	High-rise commercial tower	Mixed-use supertall tower
Primary AI Application	AI-integrated IoT sensors with predictive BMS	AI-enabled HVAC optimization and energy monitoring	AI-based occupancy analytics and predictive cooling	AI-regulated façade and airflow management
Reported Energy Impact	~70% reduction	~40% reduction	~30% reduction	~35% reduction
Technical Feasibility	Advanced BIM–IoT–AI interoperability; high digital maturity	Emerging AI integration within Indian infrastructure	Scalable AI systems in dense vertical context	Complex façade-AI integration with environmental modeling
Economic Feasibility	Strong lifecycle ROI through operational savings	Reduced operational expenditure; scalable in developing economy	Reduced O&M costs in energy-intensive skyscraper	Long-term infrastructure performance savings

Environmental Feasibility	Near net-zero performance; highest BREEAM rating	Reduced cooling loads; improved thermal efficiency	Reduced peak loads; improved air quality	Adaptive thermal performance and wind-responsive optimization
Social & Governance Feasibility	Strong EU regulatory framework; high occupant engagement	Aligns with Smart Cities Mission & GRIHA; requires skill development	UK sustainability compliance; strong building regulations	Supports national green building policies and urban resilience planning

Source: Author

5. Feasibility Analysis

The feasibility of **Artificial Intelligence driven sustainable building optimization** depends on a complex interplay of technological readiness, financial viability, environmental benefits, human adaptability, and policy support. This section evaluates these five key dimensions to determine how Artificial Intelligence can be effectively integrated into sustainable and resilient construction systems.

5.1 Technical Feasibility

Advancements in machine learning (ML**)**, data prediction tools, and smart sensor systems have made AI integration in sustainable construction increasingly practical. AI powered Building Information Modeling (BIM) and digital twins support real-time monitoring and predictive control, improving building performance and energy efficiency (RTF, 2024).

Tools such as Grasshopper's Rhino based Galapagos plug-in, Dynamo is a visual programming tool by Autodesk Revit, and Parametric design tool Marionette help optimize design parameters, achieving 20–30% energy savings and enhanced indoor comfort (Adewale, 2024). AI also strengthens resilience by simulating extreme weather conditions like floods or heatwaves to test structural performance and recommend adaptive design solutions. AI platforms use predictive modeling to detect potential vulnerabilities and ensure long-term building performance and resilience.

AI adoption depends on smooth data sharing between systems and reliable online storage and processing systems to function effectively. In India, initiatives like Digital India and the Smart Cities Mission are improving digital readiness, but uneven smart devices and sensors still limits large-scale deployment. Strengthening data frameworks will be key to scaling AI-driven sustainable and resilient infrastructure.

5.2 Economic Feasibility

The initial capital investment in AI technologies like sensors, data platforms, and cloud computing can be significant. Yet, evidence shows that the long-term economic returns outweigh these costs. AI enabled optimization leads to 15–30% reductions in energy

expenditure and 20–25% savings in maintenance costs through predictive maintenance and operational analytics (Labs, 2024) AI driven material optimization reduces over-ordering and waste, while intelligent construction scheduling tools improve workflow efficiency, minimizing delays and idle resources. This integration leads to shorter project timelines, reduced lifecycle costs, and higher productivity (Dalia Mohammed Talat Ebrahim Ali, 2024).

Economic feasibility also extends to resilience value the financial advantage of buildings designed to withstand and recover from disruptions. AI powered predictive monitoring minimizes post-disaster repair costs and extends asset life by identifying system vulnerabilities before failure. In climate-sensitive regions, resilient buildings supported by AI data frameworks maintain functionality during extreme events, protecting both occupants and economic assets.

In India, mechanisms such as green bonds, IGBC/LEED certifications, and public and private partnerships are fostering AI based sustainable construction. As AI technologies mature and hardware costs decline, accessibility for small and medium enterprises (SMEs) will further enhance cost-effectiveness and scalability.

5.3 Environmental Feasibility

AI plays a transformative role in achieving environmental sustainability and climate resilience. It minimizes carbon emissions, optimizes energy and water systems, and supports circular resource use. AI-driven energy management systems analyze real-time data on heating, cooling, and lighting to dynamically adjust building operations, improving efficiency while maintaining occupant comfort (Cove, 2024).

AI enhances environmental resilience by enabling predictive simulations that anticipate climatic variations and resource stresses. AI tools optimizes building envelopes for thermal performance and energy adaptability, ensuring long-term comfort and low energy demand even under shifting climatic conditions. AI-powered BIM platforms allow architects to test design alternatives for embodied carbon, material reuse, and energy resilience, aligning with India’s Net Zero 2070 Vision.

Additionally, AI aids in waste reduction, forecasting material requirements and improving logistics for recycling and reuse. These tools enable architects and engineers to develop designs that are both sustainable and adaptive, ensuring buildings remain functional, efficient, and environmentally responsive throughout their lifecycle.

5.4 Social and Ethical Feasibility

AI adoption in sustainable and resilient construction depends heavily on workforce readiness and ethical deployment. As AI transforms architectural and construction workflows, architects, engineers, and facility managers must be equipped with digital

literacy and analytical skills to interpret and apply AI-generated data effectively (Adewale et al., 2024).

From a resilience standpoint, AI systems support community safety and adaptability by offering real-time alerts, predictive evacuation models, and disaster-preparedness tools. AI-powered smart buildings can automatically adjust to emergencies—managing ventilation, lighting, and energy loads—to protect occupants during adverse events.

Moreover, human-centric AI enhances occupant comfort and well-being, maintaining optimal indoor environmental quality based on real-time preferences and conditions (Dalia Mohammed Talat Ebrahim Ali, 2024). To ensure social trust, ethical frameworks must address data privacy, algorithmic bias, and transparency. Inclusive training initiatives and open-access AI tools can bridge the digital divide, ensuring resilience benefits are equitably distributed across communities.

5.5 Policy and Governance Feasibility

Robust policy and governance frameworks are vital for integrating AI into sustainable and resilient built environments. Existing rating systems such as LEED, BREEAM, and GRIHA have begun incorporating performance-based metrics, yet AI-specific resilience indicators are still under development (Adewale et al., 2024).

AI can support governments in urban risk mapping, energy resilience planning, and post-disaster recovery analysis. Integrating AI within frameworks such as India's Smart Cities Mission, National Building Code (NBC), and National Disaster Management Authority (NDMA) can strengthen proactive resilience strategies. AI-based automated compliance systems also streamline adherence to zoning laws and environmental regulations, ensuring efficiency and transparency.

To mainstream AI for resilient construction, policymakers should establish AI governance standards focused on ethical data use, interoperability, and accountability. Incentives for AI-enabled resilience innovation—such as tax credits, digital infrastructure funding, and open data initiatives—will ensure equitable, sustainable, and climate-ready urban growth.

5.6 Summary

The feasibility assessment reveals that **Artificial Intelligence driven sustainable building optimization** is both **technically and environmentally viable,** with **strong long-term economic potential.** However, its success depends on addressing **social, ethical, and policy-related challenges.** The pathway toward a resilient and AI-empowered built environment requires an integrated approach combining technological innovation, governance reform, and human-centered adaptation.

6. Discussion

The study shows that AI has strong potential to make buildings more sustainable and resilient. It improves energy use, maintenance, and design adaptability when supported by good data systems, teamwork across disciplines, and clear ethical guidelines.

6.1 Opportunities

AI introduces performance-driven and climate-adaptive design approaches through predictive analytics and generative modeling. It enables architects and engineers to anticipate environmental impacts, optimize resources, and simulate resilience strategies across a building's lifecycle. AI's *data analysis and prediction* abilities with *secure, transparent record-keeping* creating systems that are both **intelligent and trustworthy** for sustainable and resilient building management.

6.2 Challenges

Despite its promise, AI integration faces several barriers. Limited interoperability between existing digital systems and weak data governance structures pose significant barriers to AI scalability in construction. Additionally, the high upfront capital costs and scarcity of skilled professionals limit adoption, especially within developing economies.

6.3 Future Directions

The future of sustainable building lies in combining human creativity with AI's precision. Research should explore how AI supports circular design, renewable energy, and adaptive reuse. Clear resilience metrics and strong cooperation across sectors will ensure fair and sustainable adoption.

7. Conclusion and Recommendations

The feasibility study concludes that Artificial Intelligence (AI) presents a workable and transformative approach for sustainable building optimization, advancing both resilience and sustainability within the built environment. Findings indicate that AI applications can enhance energy efficiency by **15–25%,** reduce carbon emissions by up to **20%,** and improve operational adaptability across the building lifecycle. These outcomes highlight AI's technical and environmental feasibility in promoting sustainable construction practices. However, adapting economic and policy frameworks requires investment in resilient infrastructure, good governance, and workforce training to support new digital technologies. AI serves as a strategic enabler, bridging digital innovation and architectural practice to support data-informed, adaptive, and sustainable design decisions. Its successful adoption relies on robust ethical governance, transparent data management, and inclusive policies that ensure equitable access and knowledge sharing across regions.

To ensure responsible integration, **governments and industry stakeholders** should invest in comprehensive data infrastructure and establish open, interoperable digital standards. **Academic institutions** need to embed AI literacy, computational design, and ethics into their curricula to prepare a workforce capable of leveraging AI for resilient

and sustainable construction. **Policymakers** should design governance frameworks that align AI innovation with long-term environmental, social, and economic resilience goals.

Achieving meaningful transformation requires **interdisciplinary collaboration** among technologists, architects, policymakers, and environmental scientists to align AI driven innovation with ecological and societal objectives in conclusion, AI holds **immense potential** to enable sustainable and resilient built environments; however, its adoption must remain **strategic, ethical, and inclusive** to ensure long-term global impact.

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Smart Green Infrastructure and Digital Twins for Climate-Resilient Urban Systems

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Abstract: Climate risks are rapidly occurring, impacting human habitats and biodiversity, with high climatic risks like urban flooding, heatwaves, air and water pollution. These risks are compelling cities to redefine their urban planning strategies. The alarming stage is the Global South, where resources are declining, and rapid urbanization has increased vulnerabilities. This research paper examines the integration of Digital Twin (DT) and the Green Infrastructure together as a tool to develop climate resilience in cities. Exploring the case studies from global and Indian case studies, the research paper will evaluate diverse SGI applications such as urban forests, bioswales, green roofs, and stormwater retention landscapes with digital platforms that are used in real-time simulations, environmental monitoring, and online governance systems.

A cross-city review covering Delhi, Jakarta, São Paulo, Cape Town, Nairobi, and Bengaluru show a clear shift from traditional, reactive disaster responses toward proactive, data-driven resilience strategies. Examples like Jakarta's AI-enabled flood prediction systems and Delhi's expanding network of real-time air-quality sensors illustrate how digital platforms, when paired with nature-based infrastructure, can significantly enhance climate readiness even in cities facing resource constraints. This work introduces the Smart-Ecological Resilience Nexus (SERN) model, which explains how interconnected ecological assets and digital intelligence can produce continuous feedback for simulation, risk forecasting, and improved governance. Overall, the findings signal accelerating adoption of integrated Smart Green Infrastructure and Digital Twin tools across the Global South, marking a move beyond incremental adaptation. These emerging systems position cities to anticipate environmental stressors, optimize responses, and build agile, ecologically aligned pathways for climate resilience.

Keywords: Digital Twins, Urban Resilience, Nature-Based Solutions, Climate Adaptation

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1. Introduction

Every city is facing the impacts of climate change, rapid urbanization, the clearance of green surfaces, population increase, and migration towards cities have highly impacted the stress on environmental conditions and increased the vulnerabilities in the cities (IPCC,2022).

As people are migrating from villages to cities, it is expected that by 2050, over two-thirds of the global population will move towards cities, as the infrastructure of the cities is already depleted stage and demands lots of interventions that will have an impact for longer run, with a high population (United Nations, 2019). The major infrastructure issues pertain to developing countries as they are at a stage of upgradation of economy, environment, and sustainability, and have major challenges of air, water, and land pollution, heatwaves, etc. (Revi et al.,2014). The major focus of these cities' issues is to adopt nature-based solutions and integration of the base layers of the environment to safeguard the urban challenges. Degraded landscapes and rooftop farming suits best for the urban area's rejuvenation, where from the smaller scale of home to city can bring the change in environment (Pawar, M., Pawar, P., & Dhote, M. 2025).

For climate uncertainty, traditional urban infrastructure (grey infrastructure) built centrally, with regular engineered systems of drainage, transportation, and energy supplies, often falls short when faced with rising climate uncertainties (Elmqvist et al.,2019). Although these systems perform well in conditions that are known and predictable to adjust to the dynamic interplay of environmental change, the needs of society, and climate stress. For example, the use of impermeable materials can absorb water and recharge the groundwater, help in mechanically cooling the surfaces and decrease the energy demands, and contribute to heat accumulation in dense neighborhoods (Gill et al., 2007). This lacuna helps in integrating built structure with natural layers and processes with the integration of digital technologies. As Pawar and Dhote (2023) pointed out, well-planned green spaces in Delhi could reduce runoff by almost 30% and nitrogen pollution by over 45%. These natural solutions don't just filter the environment; they also bring other advantages. Pawar, M. (2025), Urban vegetation mitigates air pollution by absorbing gaseous pollutants and supporting ecological stability.

Nature-based solutions (NbS) have gained importance as a tool to tackle urban issues sustainably, while incorporating ecological, societal, and economic resources (Kabisch et al.,2017). Pawar, M. (2023) stressed the importance of aligning ecological interventions with the unique features of different urban landscapes. Their research focuses on using green infrastructure as a key policy instrument to conserve biodiversity. NbS have been shown to moderate local temperatures, improve

stormwater management, carbon storage, and strengthen biodiversity (Raymond et al.,2017). The technology integration with the NbS is called Smart Green Infrastructure (SGI), which pairs ecological design with real-time information from sensor-based technologies. For example, green roofs can moderate the soil conditions and provide effective cooling performance, improving the thermal conditions (Berardi et al.,2014). Riverside vegetation planting is a key strategy for restoring degraded river and riparian ecosystems, which sustain diverse flora and fauna and provide essential ecological services (Pawar, M., & Pawar, P., 2025). Likewise, permeable surfaces equipped with sensors can generate data on pollutant levels, water infiltration, and upkeep requirements (Shafique et al.,2018). SGI reflects a move from passive green features toward responsive landscape elements that adjust to changing conditions and support more resource management in cities (Frantzeskaki et al.,2019).

1.1. Digital Twins and Urban Climate Resilience

Digital Twin (DI) technology is increasingly influencing urban planning and infrastructure management, as it continuously updates data from the sensors, satellites, and monitoring stations, and creates a digital counterpart to real-world systems (Batty,2018). The authorities can identify the vulnerable points and conditions before events occur (Deren et al.,2021). Major Cities like Singapore, Rotterdam, and Helsinki have adopted DT platforms to manage flood risks and climate scenarios (Ketzler et al.,2020). The DT is considered one of the low-cost models, when paired with Smart Green Infrastructure, because of allows strategies to be tested virtually (Marvin et al.,2022).

Bringing together ecological systems and digital technologies improves climate resilience with better outputs continuously (Nitoslawski et al.,2021). GI advances without real-time monitoring, while digital planning tools commonly overlook ecological factors, and this separation limits understanding of shared benefits and city-wide dynamics. Integrating the two through Digital-Ecological Convergence (DEC) enables continuous environmental tracking, Stronger climate forecasting, and wider public participation. This aligns with global frameworks such as the New Urban Agenda (UN-Habitat, 2016) and Sustainable Development Goals 11 and 13, which emphasize resilient, equitable, and sustainable communities.

1.2. Research Gap and Aim

Although SGI and DT systems have independently demonstrated value, limited literature examines their combined applications to strengthen climate resilience, particularly in the cities of the Global South (Gao & Pishdad-Bozorgi, 2023). In India, programs such as the AMRUT and Smart Cities Mission have advanced digital infrastructure and green-space initiatives, yet coordination between these efforts

remains limited (Bhardwaj et al.,2021). This paper addresses this gap by reviewing international and Indian case examples of SGI and DT implementation from 2015 to 2024, assessing how these tools contribute to resilience, identifying lessons from global cases, and developing a conceptual model for integrated planning. The study introduces the Smart- Ecological Resilience Nexus (SERN) as a framework to guide planners and policymakers.

2. Literature Review

A structured literature screening process was carried out using PRISMA guidelines. A total of 448 records were identified from databases and other sources, and after removing duplicates, 385 records remained for review. Titles and abstracts were screened, leading to the exclusion of 254 studies that did not meet the relevance criteria. Full text was assessed for 131 articles, of which 87 were excluded due to limited relevance, weak methodology, or incomplete information. In the end, 44 studies were included for qualitative analysis. As the focus of this review is conceptual and exploratory, no studies were taken forward for meta-analysis.

2.1. Nature-Based Solutions (NbS) for Urban Resilience

Nature-Based Solutions (NbS) are increasingly regarded as effective strategies to enhance urban resilience by harnessing ecological systems to mitigate climate-related risks such as flooding, heat stress, and air pollution (Raymond et al., 2017). Interventions such as green roofs, bioswales, urban woodlands, and restored wetlands support environmental regulation while generating additional benefits, including biodiversity enhancement, carbon sequestration, and improvement in public health and well-being (Kabisch et al., 2016).

The performance of NbS is strongly linked to their institutional embedding, long-term maintenance, and integration within statutory planning frameworks. (Mammone et al., 2026) emphasizes that governance quality, design standards, and investment continuity significantly determine NbS effectiveness across international applications. Despite their potential, implementation is often constrained by limited technical expertise, fiscal constraints, and institutional inertia (Hobbie & Grimm, 2020). Advancing NbS requires capacity building, cross-sector collaboration, and mainstreaming ecological planning into regulatory systems.

2.2. Digital Twins (DT) in Urban Planning

Digital Twins (DTs) function as virtual replicas of physical urban environments, integrating real-time sensor data, geospatial information, and predictive algorithms to support planning and decision-making (Ketzler et al., 2020). DTs have demonstrated value in hydrological modelling, infrastructure asset management, energy system optimization, and emergency planning (Batty, 2018).

Their adoption, however, is challenged by high technological and financial thresholds, concerns over data governance, and the need for specialized interdisciplinary expertise (Dembski et al., 2020). Addressing these barriers through robust policy frameworks, investment in urban digital capacity, and standardized data protocols will be critical for their sustained application.

2.2. Integrating NbS and DT for Urban Resilience

The integration of NbS and DT platforms reflects a growing shift toward hybrid ecological-digital resilience frameworks. This convergence allows planners to evaluate how ecological interventions influence microclimates and hydrological flows, while using predictive modelling to optimize location, design performance, and maintenance (Abbas et al., 2025)

By providing accessible, data-rich interfaces that synthesize complex environmental variables, these tools effectively bridge the knowledge gap between specialized technical experts and the broader public (Chen et al., 2024; Quek et al., 2023).

2.3. Case Studies of NbS and DT Integration

International examples demonstrate the operational benefits of NbS-DT integration. In Singapore, the Virtual Singapore platform supports climate simulations alongside extensive green infrastructure deployments such as pervasive tree planting and vertical greenery systems (Bank, 2021). Rotterdam combines digital flood modelling techniques with NbS interventions such as water plazas and green corridors to create adaptive drainage and flood protection networks (Frantzeskaki et al., 2019).

These experiences underline the value of continuous monitoring, stakeholder engagement, and interdisciplinary collaboration in achieving durable urban climate resilience outcomes.

Although the integration of NbS and DT systems presents considerable promise, several technical, institutional, and financial challenges persist. Harmonizing diverse datasets, standardizing monitoring protocols, and coordinating multidisciplinary expertise require structured institutional support (Dembski et al., 2020).

Nevertheless, the potential benefits are substantial, particularly in developing inclusive, anticipatory, and adaptive climate resilience strategies (Ali, 2025). Strategic investment in digital-ecological infrastructure, open-data governance systems, and community engagement mechanisms will be central to future progress.

3. Findings and Discussion

3.1 Global case studies of Smart Green Infrastructure and Digital Twins

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A review of ten global cities reveals diverse approaches to integrating Smart Green Infrastructure (SGI) with Digital Twin (DT) technologies to enhance urban resilience:

Table 1. ***Global case studies- smart green infrastructure***

City	SGI Initiative	Digital Twin Application	Climate Resilience Outcome	Reference
Singapore	Green roofs & vertical gardens	City digital twin for heat and flood modeling	Reduced urban heat, improved stormwater management	Ali, 2025
Rotterdam, Netherlands	Water plazas, green corridors	DT for flood prediction and water management	Adaptive flood mitigation, ecosystem enhancement	Ali, 2025
Helsinki, Finland	Urban forests & green belts	DT for energy and climate modeling	Optimized cooling, reduced energy demand	Abbas et al., 2025
New York, USA	Green streets and parks	DT for air quality and heat mapping	Urban heat mitigation and improved air quality	Hobb et al., 2020
Tokyo, Japan	Roof gardens & permeable pavements	DT-based disaster preparedness	Flood risk reduction and heat stress adaptation	Prado et al., 2025
London, UK	Thames riverfront wetlands	Flood forecasting DT	Improved flood resilience and water quality	Mammone et al., 2026
Melbourne, Australia	Urban greening & park expansion	DT for carbon sequestration and biodiversity	Enhanced ecosystem services and urban cooling	Hobb et al., 2020
Barcelona, Spain	Green infrastructure networks	DT for urban energy efficiency	Reduced energy consumption and urban heat	Abbas et al., 2025

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Copenhagen, Denmark	Climate-resilient parks & water channels	DT for flood management	Minimized flood risk and improved public space	Ali, 2025
Toronto, Canada	Green rooftops & permeable pavements	DT for infrastructure monitoring	Increased flood resilience and reduced heat islands	Prado et al., 2025

Source: Author, 2025 & Published Literature

These examples demonstrate how global cities use SGI to address urban heat, flooding, and air pollution, while DTs provide predictive modeling and performance optimization. Integration of these systems enhances decision-making, reduces risk, and ensures sustainable ecosystem management.

3.2 Indian Case Studies of Smart Green Infrastructure and Digital Twins

Similarly, ten Indian cities are implementing SGI and DT approaches, although often in nascent stages:

Table 2. ***Indian Case Studies - Smart Green Infrastructure and Digital Twins***

City	**SGI Initiative**	**Digital Twin Application**	**Climate Resilience Outcome**	**Reference**
Delhi	Urban forests & green belts	IoT-enabled monitoring for air quality	Reduced PM2.5 concentrations and urban heat	Bhardwaj et al., 2021
Bengaluru	Green roofs & vertical gardens	DT for urban flood modeling	Enhanced stormwater management	Ali, 2025
Pune	Riverfront greening	DT for flood and pollution modeling	Improved flood resilience	Bhardwaj et al., 2021
Hyderabad	Urban parks and green corridors	DT for heat island simulation	Reduced local temperatures	Ali, 2025
Chennai	Coastal green buffers	DT for storm surge prediction	Minimized coastal flooding impacts	Bhardwaj et al., 2021

Mumbai	Permeable pavements in slum redevelopment	DT for drainage system modeling	Reduced flooding in vulnerable areas	Ali, 2025
Ahmedabad	Urban wetlands & bio-swales	DT for water quality monitoring	Improved urban water management	Bhardwaj et al., 2021
Kolkata	Rooftop gardens	IoT-enabled monitoring	Mitigated heat stress	Ali, 2025
Jaipur	Tree plantation and green corridors	DT for microclimate modeling	Reduced urban heat and improved air quality	Bhardwaj et al., 2021
Gurugram	Smart parks & green streets	DT for flood risk modeling	Enhanced stormwater management and urban cooling	Ali, 2025

Source: Author, 2025 & Published Literature

These Indian examples indicate increasing adoption of SGI and DT technologies through mission-driven programs such as the **Smart Cities Mission** and **AMRUT**, although full-scale integration remains limited compared to global best practices.

4. Comparative Analysis

Table 3. ***Functional comparison: Nature- Based Solutions Vs Digital Twins***

City	**NbS Approach**	**DT / Digital Planning Tools**	**Climate Challenge**	**Outcomes / Status**
Delhi	Urban forestry, water body restoration, green mobility corridors	Integrated command-control centres, urban heat maps	Heat, PM pollution, floods	Partial integration; strong potential for combined monitoring
Bengaluru	Lake rejuvenation, wetland buffers	GIS-based water modelling	Urban floods, water scarcity	Demonstrated hydrological benefits; data gaps persist

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Chennai	Blue-green infrastructure, marshland restoration	AI-enabled flood modelling	Coastal flooding, storm surge	Real-time alerts + NbS improve drainage resilience
Pune	Green street networks, riverfront ecological restoration	Smart City dashboard, IoT pilots	Heat, surface runoff	Early-stage digital-ecology linkages
Surat	Mangrove restoration, urban wetlands	Multi-hazard early warning DT	Coastal risk, cyclones	Notable convergence; strong governance model
Ahmedabad	Heat-action NbS (parks, shade networks)	Satellite heat analytics	Heat waves	Leading heat-resilience city; DT + NbS alignment emerging

Source: Author

5. Conceptual Model: Smart- Ecological Resilience Nexus (SERN)

Based on these findings, this study proposes the Smart- Ecological Resilience Nexus (SERN) framework.

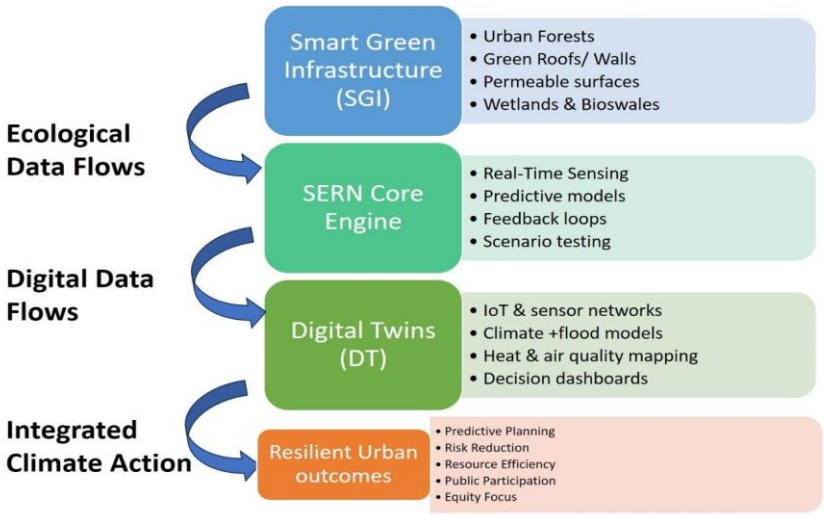


Figure 1. *Conceptual schematic of SERN showing ecological interventions, digital twin integration, data feedback, and urban resilience outcomes*

Source: Author

The findings highlight that pairing Smart Green Infrastructure with Digital Twin Systems offers a robust approach to urban climate resilience. International examples such as Singapore, Rotterdam, and Helsinki show how advanced simulation tools are being used to manage flooding, heat, and energy demand at a city scale (Abbas et al., 2025; Hobb et al., 2020). In India, similar efforts are emerging through national missions and local pilot projects, signaling growing interest in linking ecological planning with digital monitoring and predictive tools (Ali, 2025). Evidence from multiple contexts indicates that green infrastructure contributes to heat reduction, stormwater absorption, and cleaner air (Prado et al., 2025), while digital twins support early-warning systems, real-time oversight, and data-guided decision-making (Mammone et al., 2026)

The SERN framework underscores the value of integrating ecological and digital systems to support adaptive planning. For Indian cities, moving this approach to scale will require investment in capacity-building, institutional coordination, digital infrastructure, and community involvement. More broadly, policymakers should promote cross-sector collaboration, open-data standards, and planning regulations that formalize eco-digital integration (Hobbie & Grimm, 2020). Cities that pursue these pathways can shift from reactive approaches to proactive resilience, enhancing quality of life, environmental health, and long-term sustainability.

Hobbie & Grimm, 2020

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Supplementary Materials/ Appendix A

None

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TRACK 03
RESILIENT URBAN AND RURALSCAPES



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From Heritage Waterscapes to Resilient Publicscapes: A Blue–Green Framework for Bijapur

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Abstract: Located in the arid Deccan plateau of Karnataka, the 'late medieval' Bijapur is stratified into distinct military, cultural and civic infrastructure centred around its water systems which shaped the culture and evolution of the city. The subterranean karez network, monumental stepwells, and seasonal tanks became vital spaces that not only sustained life but also acted as civic spaces and ecological buffers. With rapid urbanization, these systems have become fragmented and undervalued, yet, they hold immense potential for a resilient, heritage-informed public realm. This inquiry examines Bijapur's waterscapes to reimagine an urban public spine strategy: a blue-green network that integrates heritage with eco-sensitive urban design. The paper advances a design framework rooted in theory, through observing the negotiated thresholds of socio-cultural, ecological and spatial layers of Asar Mahal using an interpretive theoretical foundation - A Publicness Assessment Framework (5A PAF), of Agency, Area, Arrangement, Activity, and Atmosphere (5As) to facilitate a spatial urban resilience strategy of Context, Conserve, Change, Connect, and Celebrate (5Cs). Asar Mahal is a central node in a rural-urban transect of historic water architecture. The study is supported by archival mapping, municipal records, satellite imagery, and on simple on-site field observations. The intent is to examine the historic and explore how water can once again structure a resilient urban realm and aid the discourse on sustainable urban systems and a new urban public realm - a network of cooling waterscapes that absorbs the adverse effects of climate change (low carbon), reduces flood risks (permeable) and nourishes biodiversity, while enhancing its place identity and fostering a vibrant public life.

Keywords: public space; urban heritage; traditional water systems; urban design; nature-based design; blue-green infrastructure

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1. Background

Situated in the semi-arid Deccan plateau, the city of Bijapur (Vijayapura), flourished under the Adil Shahis who nurtured the symbiotic relationship between its water infrastructure and social fabric (Nayeem, 1996; Michell & Zebrowski, 1999) and the city today stands testament to the hydraulic ingenuity of its rulers. This is evidenced through the water infrastructures operating along a rural-urban continuum: the subterranean *karez* systems carrying water from peripheral reservoirs and feeding the monumental *bavdis* (stepwells), defensive moats and central ceremonial tanks such as

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the Asar Mahal Tank. These water supply systems were civic instruments that articulated Bijapur's cultural, ecological, and spatial life (Shokoohy, 2003) as they were not only designed to harvest, store, and distribute water but also to facilitate public spaces and climate responsive architecture that mediated between community and environment in harsh climatic conditions, erratic rainfall and scarce groundwater availability. Today, in the postcolonial era, this once-living water network has lost its continuity and has become background relics due to neglect and development pressures. However, the remnants of these waterscapes continue to articulate the urban experience, offering opportunities to design a resilient public spine that integrates ecological performance, heritage, and civic life.

2. Conceptual Design Research Approach

2.1. Theoretical Foundation: Defining Publicness and Urban Resilience

The study is structured in the theoretical construct of Publicness in relation to Urban Resilience. Firstly, publicness is traditionally defined in terms of ownership and legal access - the state controlled 'public' and the privately controlled 'private' (Benn & Gaus, 1983; Varna & Tiesdell, 2010) in the west. Secondly, urban resilience, in the context of Bijapur, refers to the assembly of ecological artifacts - moats, tunnels, tanks, reservoirs - and the socio-political forces that govern them. This lens views the city as a series of integrated strata (subterranean, surface, and monumental). However, this research hypothesizes that in the Indian context, publicness is defined not as a binary state, but as a series of negotiated thresholds (Kaviraj, 1997) which were responsive to nature. Underlining Chatterjee (2004), the public realm in heritage cities like Bijapur functions as a 'social commons', a space for 'political society' where use is mediated by religious and gendered protocols rather than legal titles. Following Madanipour (2003), the research acknowledges the modern 'fragmentation' of these ecological and resilience layers, where the historical continuity between water infrastructure and civic life has been severed.

2.2. Design Research Methodology

The study adopts a qualitative and site-based research design that combines field observation, archival analysis, and spatial interpretation to evaluate the morphology, connectivity, and heritage significance of Bijapur's waterscapes. The archival and literature studies consisted of reviewing ASI records, gazetteers, colonial-era maps (1792–1910), and Deccan Sultanate hydraulic treatises to contextualize construction, heritage values, and hydraulic networks. Between February and September 2025, fieldwork was conducted across the Bijapur fort precinct and beyond to explore the spatial articulation of the city's waterscapes. Remote Mapping through satellite

imagery and figure-ground diagrams helped identify spatial footprints and the resilience thresholds. The perceived temperature and experiential quality were observed through people-watching, walking experiences and interactions with the community. To cross-verify perceptual and observation data, simple thermal readings through infrared thermometer were recorded between the shaded, open-to-sky and water adjacent areas.

2.3. The 5A-5C Framework

The 5A Publicness Framework of Agency, Area, Arrangement, Activity, and Atmosphere, is an assessment tool formulated by Karadagi, 2021 in previous research to evaluate these thresholds. The 5A framework is not proposed as a new theory of publicness, but as a synthetic operational tool that translates established public space and informality theory into spatial diagnostics. Activity and Arrangement are derived from the spatial theories of diversity and presence of design features of Jacobs (1961), Carmona (2015) and Whyte (1980). Atmosphere reflects the experience and perceptions of space, influenced by Gehl's (1987) observations on social life. Agency (ownership and control) is examined through Ananya Roy's (2005) epistemology of informality, acknowledging that 'informal' occupancy is a legitimate socio-cultural force in the management of heritage infrastructure.

Table 1. Elucidation of the theoretical foundation for the adapted 5A publicness assessment framework. 2025, Karadagi.

Framework	Dimension	Theoretical Anchor	Definition / Application in Research
5A: Publicness Assessment (Diagnostic Tool)	**Agency**	Roy (2005); Benn & Gaus (1983)	**The Management Layer:** Evaluating the "negotiated thresholds" of ownership, control, and informal occupancy at the Asar Mahal datum.
	Area	Carmona (2015); Madanipour (2003)	**The Accessibility Layer:** Mapping the physical footprint and the degree of "fragmentation" between heritage nodes and the civic realm.
	Arrangement	Whyte (1980); Jacobs (1961)	**The Spatial Layer:** Analyzing the physical configuration, edges, and thresholds that define the circulation of people and water.
	Activity	Gehl (1987)	**The Social Layer:** Documenting the ritualized use, gendered presence, and "Kinetic" social life within the publicscape.

	Atmosphere	Kaviraj (1997); Karadagi (2021)	**The Perceptual Layer:** Correlating microclimatic cooling (water/shade) with the social perception of "welcome" and publicness.

Through decoding the spatial logic, the paper utilizes the **5A Publicness Assessment as a diagnostic** to inform a **5C Urban Resilience Strategy (Context, Conserve, Change, Connect, Celebrate)**. The aim is to corelate the observational framework with policy, framing the proposed **Blue-Green Spine** as a theoretical planning proposition. The objective is to integrate socio-cultural thresholds with contemporary ecological design through a multi-layered urban spine.

2.4. Rural-urban transect and site selection

A rural-urban transect along the MG Road axis identifies key components of the historic water network (Figure 1). Spatial analysis included decoding the figure-ground, terrain, and patterns of everyday occupancy. For the scope of this inquiry, **Asar Mahal** is utilized as the **primary design observation datum**, a representative 'slice' of the Citadel. The dimensions of **Area and Arrangement** are applied to evaluate how its specific religious thresholds dictate accessibility and spatial footprint within the larger transect.

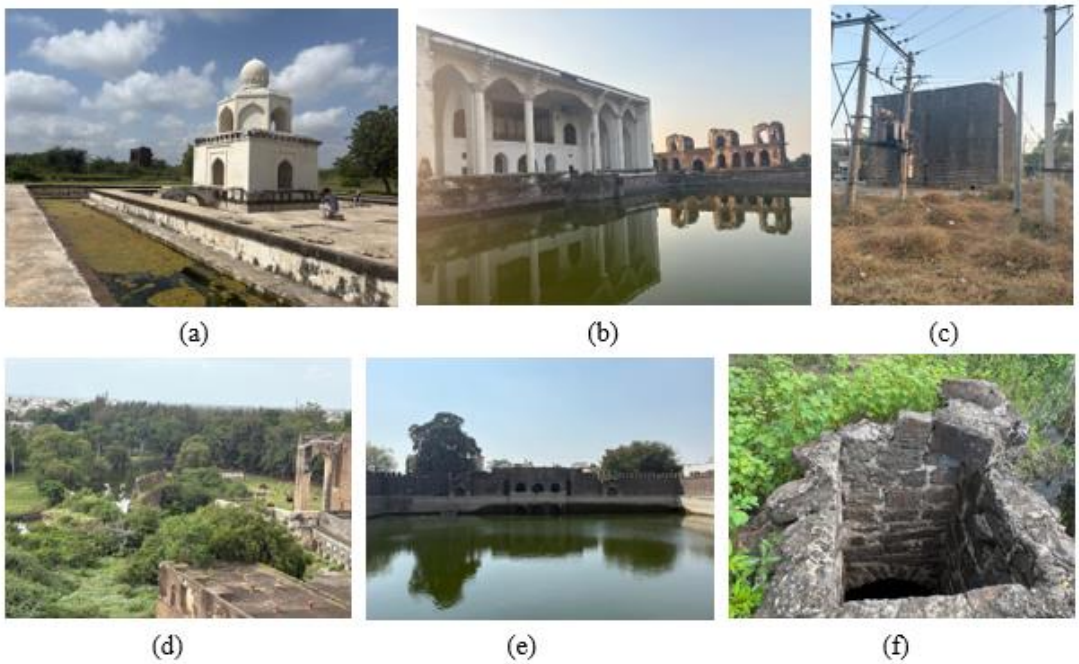


Figure 1. (a) Jala Mahal summer palace at Kumatagi; (b) Asar Mahal; (c) Water Gunj; (d) Moat & Gagan Mahal; (e) Taj Bavdi; (f) Surang Bavdi (air vent). 2025, Karadagi.

For the scope of this paper, a theoretical - interpretive design research approach is adopted. Spatial observations are used illustratively and not as empirical validation. The intent is not to overly generalize from Asar Mahal, but to demonstrate how heritage

waterscapes can be read as socio-ecological infrastructures through the proposed 5A-5C framework. To ground this framework, it is essential to first understand the historical imperative that drove Bijapur's hydrological engineering.

3. Bijapur's Water Systems: Historical Context

3.1. Historic and Geographic Setting of Bijapur

One of the first markers of Vijayapura, as its name and gazetteer excerpts suggest, was a victory pillar commemorating 'Vijaya' (victory) established before the 7th Century Kalyani Chalukyan Era (Campbell, 1884). By the 14th century, the current site of the city was the capital of the Devgiri Yadavs. The region witnessed Muslim invasions and was an important stronghold of the Khaljis, as evidenced by the Karim-ud-din Mosque built in 1316. Bijapur then changed hands to the Tuglaqs and the independent deccan Bahamanis. In 1458, Mahmud Gawan became its governor, and in 1490, after Gawan's death, Yusuf Adil Khan, his adopted son, declared independence from the Bahmani sultan.

With an average rainfall of 580 mm, concentrated in the monsoon months, the city needed innovative mechanisms to sustain. The Adil Shahi rulers leveraged the gently undulating and basaltic plateau and Bijapur's saucer like topography to engineer the city's urban form and water systems (A. Hullur, personal communication, August 2, 2025). The city's roughly oval citadel / Ark Quilla (0.3sq.km.), used by the royals, was sited on a mound, the highest point, enclosed by moats and walls which acted as defensive and security systems. A second irregular-oval in plan fortification and moat system (7.5sq.km.) enclosed the urban settlements, approximately 3.25 kilometres along its major east-west axis and 2.8km along the north-south axis.

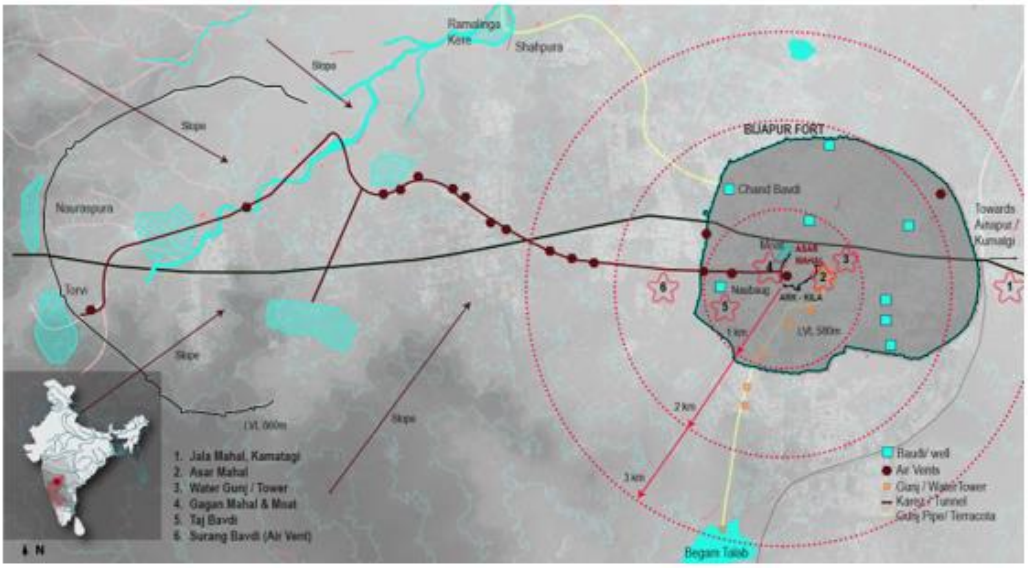


Figure 2. Water systems showing the rural-urban continuum (extrapolated from archival maps and literature references). 2025, Karadagi.

3.2. City & Water - a connected system

The *karez* network linked surface tanks like Begum Talab with underground infiltration galleries and vertical air shafts (*surang bawdis*). The Ramalinga Kere had a dam and sluice gates to regulate the flow of water due to the vagaries of nature. The porous basalt allowed infiltration and recharge, forming natural aquifers and allowed water to percolate into the tunnels. The terrain's natural slopes guided the direction of flow of water through gravity. Air vents, Persian wheels and water towers or gunjs were introduced as engineered moderators of the terrain, allowing water to be pumped up where the contours were constraints.

The larger reservoirs such as the Begum Talab and the Jala Mahal Summer Palace, Kumatagi, located in the peri urban fringes and rural areas had a cooling effect on their surroundings, bringing in the water with the breeze (S. Deshmukh, personal communication, May 3, 2025). Stepwells and tanks acted as environmental regulators, religious and cultural nodes. An observation of the figure ground shows a large open to built ratio - less than 35%, creating a sponge city-like scenario, enabling high water percolation and aquifer recharge.

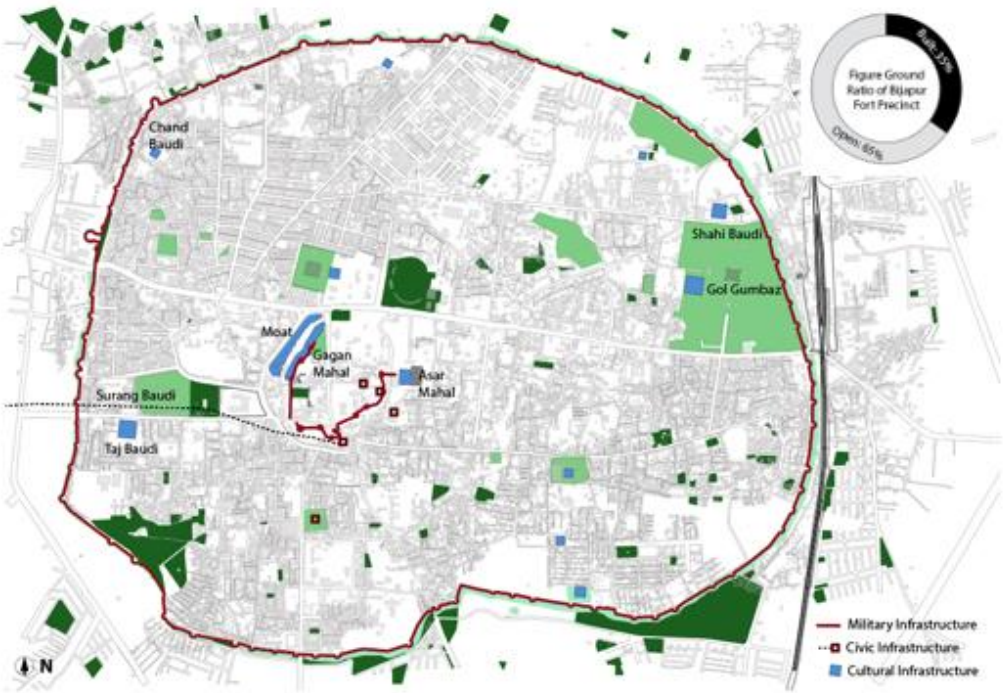


Figure 3. Figure Ground, military, civic and cultural infrastructure of Bijapur. 2025, Karadagi.

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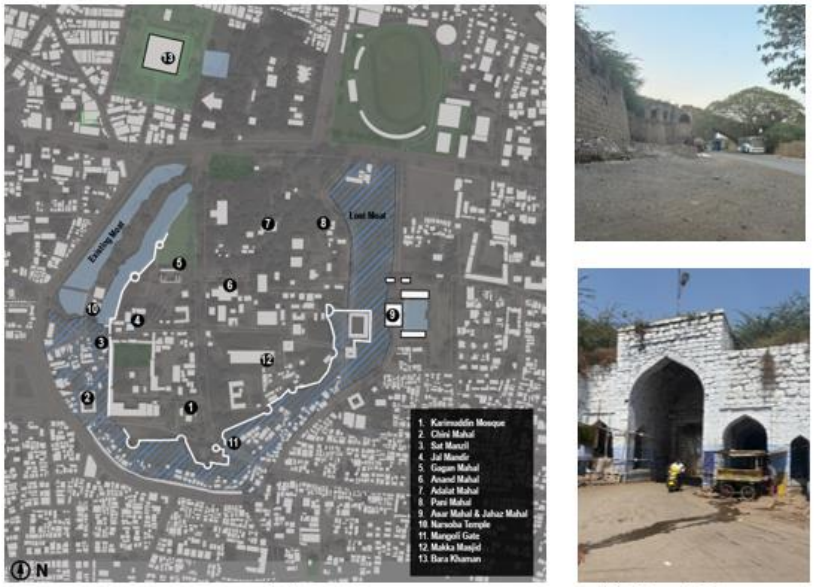
4. Case Study: Asar Mahal Tank

4.1. Context and Spatial Setting

The Asar (Holy) Mahal, one of the prominent living heritages near the citadel ***(Conserve),*** was built by Sultan Mahmud Adil Shah around 1646 to serve as a public Hall of Justice and was also called Dad Mahal or Adalat Mahal. Its function changed to a Relic Palace for the reception of sacred hair from the Prophet Muhammad's beard, brought to Bijapur by Mir Muhammad Salli Hamadani, a Persian Sufi saint. A new Adalat Mahal was built in the citadel under the instructions of the Mughal Emperor Shah Jahan (Campbell, 1884; Philon, 2014). Hence, historically, it functioned as both a ritual site and civic space, linking water provision, social congregation, and urban circulation.

4.2. Area: Spatial Extent and Urban Integration

Located in the urban core ***(Context),*** the Mahal precinct sits on a 1.6-hectare parcel of land and the Asar Mahal Tank, a rectilinear ceremonial water body in its centre, fed by the Begum Talab and Torvi conduit, occupies about 0.46 hectares (90m x 52m). The palace was saved from the general ruin that befell other palaces because of the reverence it enjoyed due to the relic of the Prophet. The precinct is surrounded by tightly packed residential or mixed-use settlements and dilapidated tin roof houses along the moat. The precinct acts as a thoroughfare and is accessible to pedestrians both from the north and the south ***(Connect),*** linking the Tank to streets and surrounding neighbourhoods.



(a) (b) Top & bottom

Figure 4. (a) Overlay of building footprint on Satellite imagery showing Asar Mahal and its relation to the citadel (b) Top: Bridge between Asar Mahal and Citadel; Bottom: Asar Mahal Gate. 2025, Karadagi.

4.3. Arrangement: Configuration, Access, and Circulation

The longer axis of Asar Mahal is along the north-south, with the Mahal situated on the west of the tank and the ruins of Jahaz Mahal (Ship Palace) on the north. This orientation allows the cool breeze from the water to be carried to the colonnaded verandah. The publicness is highest in these thresholds (evenings) where children play and women socialise, the arrangement supporting ritual, leisure, and social interaction, fostering a calm everyday urban vitality ***(Celebrate).*** The flexible perimeter spaces allows community personalisation without compromising heritage integrity ***(Change).*** The Mosque itself is restricted to women. A three-day annual festival in honour of the Prophet is held here, known as the Asar Urus (Relic fair). The stepped edges and colonnaded thresholds visually connect the sacred sanctum to the water, showcasing a design logic balancing hydraulic buffering with public engagement and accessibility. Thermal measurements at Asar Mahal Tank during May 2025 (ambient ~36 °C) showed temperatures 5-6 °C lower within the precinct - demonstrating the passive cooling effect of evaporative water bodies and masonry massing (Govindankutty, 2020). The low built to open ratio (15%) demonstrates the permeability of land to recharge ground water.

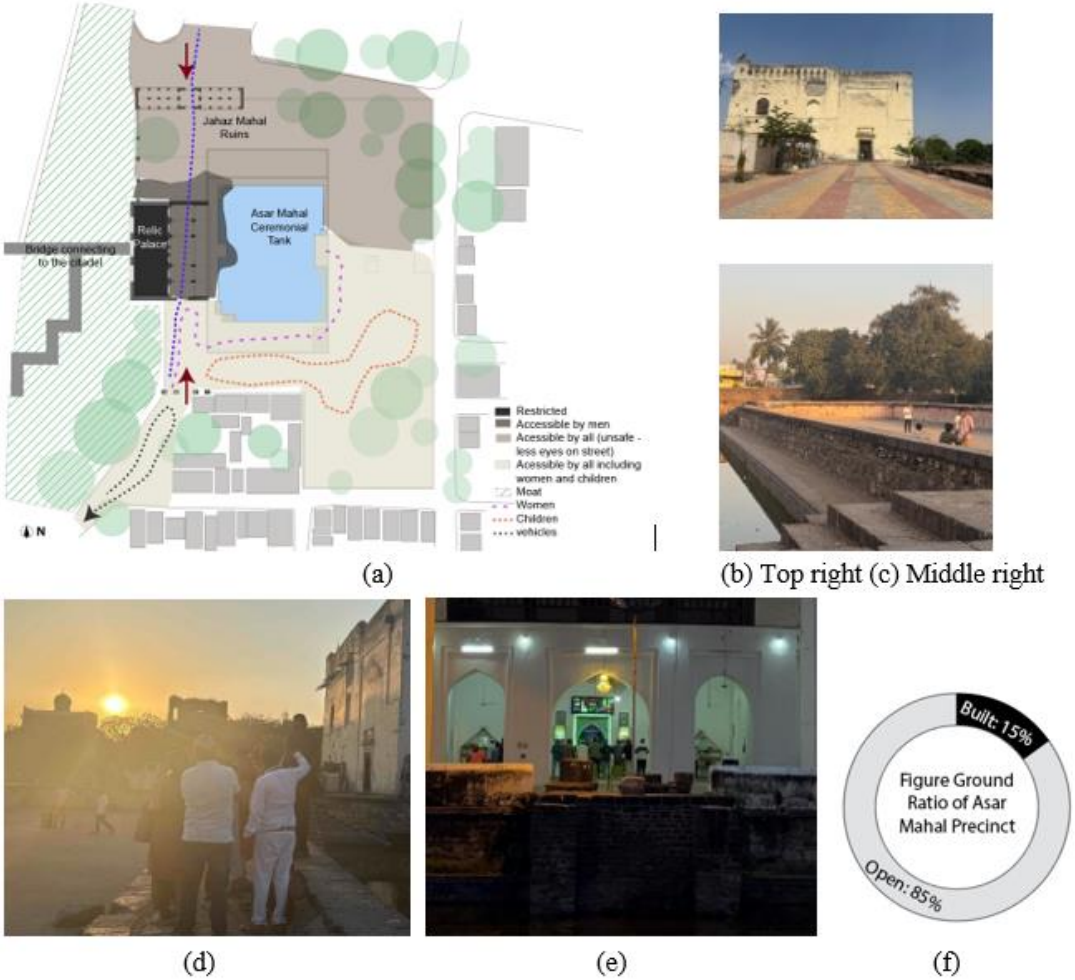
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These features enable legible circulation, visual permeability, and functional zoning, translating morphological clarity into and urban resilience strategy.

Table 2. Localised cooling effect at Asar Mahal Tank (May, 2025). 2025, Karadagi.

Site	Publicness (Area, Arrangement)	Thermal reading (°C)	Observations
Asar Mahal: Mosque & Ceremonial tank	Area: Urban, near city centre Arrangement: Rectilinear basin adjoining colonnaded arcade; shaded edge transitions	Adjacent Street (Urban Heat Island Zone): 39.2 Water Edge: 33.5 Relative Cooling: –5.7*	Alternating shade and breeze create local microclimatic pockets; strong human comfort zones.

* Thermal data based on field readings (simple infrared thermometer) between 10:00 AM–3:00 PM



(a) (b) Top right (c) Middle right (d) (e) (f)

Figure 5. (a) Spatial configuration of Asar Mahal (b) Entry to Asar Mahal: Less used in the afternoons (c) Social interactions at 4:30pm (d) Children playing and guided-tour group interacting at 5:30pm (e) Men praying under the shaded colonnade at 6:30pm (f) Figure Ground Ratio of Asar Mahal. 2025. Karadagi

5. Discussion & Conclusion: From Heritage to Blue-Green Spine

The research proposes that Publicness and Urban Resilience be adopted as diagnostic and assembly tools for future master planning. Rather than treating heritage sites as "buffer zones" that inhibit development, policy should frame them as active infrastructure that anchors the city's resilience.

5.1. Reconnecting the Asar Mahal Datum to the Citadel Core and Blue-Green Spine

Current heritage policy often isolates Asar Mahal, treating it as a static social node. A Resilience Policy approach recommends re-establishing the physical and hydrological link between the Asar Mahal tank and the Citadel moat system.

Recommendation: Implement a "Threshold Management Zone" that bridges the religious-gendered sensitivity of Asar Mahal with the public transit needs of MG Road. This is envisioned as a multi-modal street section that reconfigures the MG Road-Citadel interface. This shift replaces the existing vehicular barrier with a stratified **Publicscapes:** a 3-meter pedestrian-priority promenade integrated with a linear bioswale network. By utilizing the natural gradient of the terrain, the bioswales act as a surface-level extension of the historic karez, filtering run-off before it enters the rejuvenated moat system. This configuration effectively manages the 'Area' and 'Arrangement' (5A) by creating a permeable social and ecological edge

5.2. Leveraging Civic Anchors: Bara Khamman and the New Stadium

To prevent the "monumental isolation" of the Citadel, policy must leverage civic nodes like the Bara Khamman and the Stadium as catalysts for the Blue-Green Spine.

Recommendation: Develop a Civic-Heritage Corridor that utilizes the open space of the Stadium and the monumental scale of Bara Khamman to anchor the "Celebrate" (5C) strategy. This policy would allow for "Occupancy Urbanism" (Benjamin, 2008), where public events and rituals are permitted within heritage-adjacent zones, increasing the "Agency" (5A) of the local community. Following Mehrotra’s (2008) discourse of the 'Kinetic City, policy that anchors the New Stadium and Bara Khamman and facilitate the flexible 'social commons' described by Chatterjee (2004) is essential. This ensures that the Blue-Green Spine serves as a performative layer that accommodates both historic preservation and contemporary civic life.

5.3. Rejuvenating the Encroached Moats as Ecological Infrastructure

The moats currently function as "fractures"—areas of neglect and informal encroachment. Policy must shift from "Clearance" to "Ecological Restoration."

Recommendation: Adopt Nature-Based Solutions (NBS) to transform the moat vestiges into a decentralized Sponge-City network. By integrating the moats with the subterranean karez system, the city can mitigate flash flooding and urban heat islands. This policy ensures that the moat is no longer a backyard for waste, but the primary Blue-Green spine of the Citadel.

Table 3. Proposed 5C Urban Resilience Strategy Framework. 2025, Karadagi.

5C Strategy (Policy Tool)	5A Diagnostic Input (Area & Arrangement)	Urban Resilience Strategy Application: The "How" of Master Planning
Context	**Arrangement**	Uses the historical arrangement of the Asar Mahal tank to define the hydrological logic for the entire Citadel precinct, ensuring new developments respect the ancestral water "strata."
Conserve	**Area**	Identifies the "Area" of encroached moat vestiges as high-priority zones for **Nature-Based Solutions (NBS)**. Policy mandates reclaiming these footprints to restore the city's "Sponge" capacity.
Change	**Arrangement**	Reconfigures the street arrangement of MG Road. By leveraging the **New Stadium** as a contemporary anchor, policy shifts the road from a vehicular barrier to a multi-modal, pedestrian-friendly threshold.
Connect	**Area & Arrangement**	Physically links the spatial gaps between the **Bara Khamman**, the Citadel moat, and the Asar Mahal datum. It translates isolated "Areas" into a continuous Blue-Green Urban Spine.
Celebrate	**Arrangement**	Designs for **"negotiated thresholds."** Policy ensures that the physical arrangement of the spine supports the ritual vibrancy and social access of the heritage public realm.

6. Conclusion: A New Discourse for the Semi-Arid City

By integrating the Asar Mahal datum back into the larger Citadel assembly, Bijapur can transition from a city of "isolated artifacts" to a city of "interconnected publicscapes." While this study is grounded in Bijapur, the combined 5A–5C framework is transferable to other semi-arid historic cities where traditional water systems, layered urban form, and socio-religious thresholds structure public life. The theoretical framework can be applied in comparable contexts such as Bidar and Gulbarga, which exhibit similar rural-urban hydrological continuities, monument-centric water ecologies, and negotiations in the public realms.

The 5A-5C readings and recommendations should be read as theoretical propositions derived from spatial interpretation rather than statistically generalizable results. The objective is to contribute a conceptual lens for heritage-led resilience planning, not a performance evaluation.

Ultimately, the Blue-Green Spine is a policy proposition for Urban Resilience: an integrated assembly of civic memory, waterscapes, and the civic-social life. It demonstrates that the restoration of hydrological logic is not a mere return to the past, but a structural necessity for a resilient, memory-rich, and climate-attuned urban future.

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AI Disclaimer: The author confirms that the core intellectual content, data, analysis, and the '5A/5C' frameworks presented in this paper are their own original work. During the preparation of this manuscript, AI-assistant (ChatGPT 4.0. and Gemini) was used to improve grammar, clarity, flow and to assist with word count reduction. After the use of these tools, the author conducted a full review and take complete responsibility for the accuracy, originality, and final content of this publication.

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Urban Riverfront Development: Issues And Concerns from Users' Perspective with Emphasis on Flood Resilience

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Abstract: Historically, rivers have served multiple roles, including trade routes, markets, industries, and transportation, and have played a crucial part in building civilizations around them, thereby shaping societies and giving them an identity. Over time, the meaning of riverfront development has changed. It is viewed as an inclusive space for engaging community interaction, facilitating social, cultural, and religious gatherings that are sustainable, safe, and accessible, both physically and visually.

Understanding users' perspectives and concerns is vital for designing riverfronts that go beyond aesthetics, ensuring they are sustainable, safe, economically viable, and functionally effective. Flood resilience on the riverfront plays a crucial role in shaping infrastructure, ensuring that developments are adaptive, durable, and functional with an understanding of river characteristics.

This research aims to understand people's perceptions of riverfronts with the upcoming riverfront development case in Pune, focusing on the spatial quality, infrastructure, facilities, and flood resilience through a questionnaire survey and interviews. The areas selected were along the Mutha riverfront near Mhatre bridge and near Omkareshwar temple near the core city area. The analysis and findings from this research are based on the online survey (41 respondents) and personal interviews (8 respondents) with a total sample size of 49 respondents. Major concerns raised were related to flood risk, exposure and susceptibility to support mitigation measures, capacity-building efforts to combat flood risks, protect ecosystems, and ensure the safety and well-being of urban communities. The conclusions derived from the research can empower architects and planners to design the riverfronts that truly reflect people's perceptions of the built environment, especially ensuring flood resilience.

Keywords: Role of rivers; Riverfront development; User Perception; Sustainability; Flood resilience

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1. Introduction

Rivers have played a vital role in human settlement since ancient times; they provide rich soil, water, and a connector to go around (Vriddhi, 2017). Cities and towns along

rivers are a principal example of a traditional rural human settlement, land use, or sea use that reflects a culture or human interaction with the environment and is directly linked to events or living traditions, ideas or beliefs, and literary and artistic creations of exceptional universal significance. There are elements of religious, spiritual, and ecological significance in these cities and towns. (Kalita, 2017).

Over time, the purpose of riverfront development has shifted from purely functional to inclusive civic spaces that encourage ecological restoration, cultural expression, and community interaction. As Kevin Lynch described in The Image of the City, “edges” act as boundaries and transitions (Lynch, 1960, p.47); in the case of rivers, these edges become dynamic interfaces connecting the built environment with open landscapes.

Today, riverfronts are viewed as multifunctional spaces that support community gatherings while ensuring sustainability, accessibility, and resilience. They also provide vital leisure landscapes for recreation and relaxation.

Planning these riverfront edges requires knowledge about planning and construction process, consisting of the perception and views of the users. In today’s scenario, users' perception and inclusion of propelling bodies are essential elements lost from the developing process (Khan, 2022).

The success of riverfront development ultimately depends on fostering meaningful human interaction with the river, making engagement with water central to creating vibrant, functional, and resilient spaces (Shrestha, 2019).

The river dynamics have become unpredictable because of uncertainties of climate due to global warming. Flood resilience has become a new approach to addressing environmental disturbances.

This research aims to explore a riverfront development case in Pune from a user perspective, with emphasis on flood resilience. The riverfront of Pune is currently undergoing development, and the findings of the research can help develop more sensitive and user-friendly proposals for the benefit of the local community.

The research questions are–

1. What are the riverfront features and user preferences related to it
2. What are the preferred activities suggested by the users along with the riverfront
3. What are the problems during floods especially, faced by the users using / staying near the riverfront
4. What are the user preferences to mitigate floods and increase flood resilience

2. Literature Review

2.1 Urban Riverfront Development

In urban fabric settled around rivers , interactions between citizens and water take place through the “waterfront” (Timur, 2013).Its meaning differs from one author to another,

and its academic interpretation has evolved. (Silva, 2004) describe it as “the direct contact zone between the river and the first line of buildings”. For (Moretti, 2008), it is “the urban area in direct contact with water” (VianJuan, 2021).

Urban riverfronts are reimagined with trails, plazas, parks, housing, restaurants, shops, offices, cultural and recreation spots, and other amenities that draw residents, businesses, and visitors to the water (Kalita, 2017).

Waterfronts, as dynamic edge environments, have historically supported diverse uses—from ports and military zones to recreation and transport—but have also experienced decline due to evolving land-use patterns over time (Babalis, 2017).

Riverfront development offers an opportunity to shape a strong urban identity while sustainably integrating the river through groundwater recharge, biodiversity conservation, and the creation of diverse, accessible public spaces. (Rathore, 2019).

2.2 User’s Perspective

Riverfront scenery reflects a city’s identity and cultural meaning, making it essential to quantify human-centric visual perception to guide landscape design and enhance residents’ well-being (Zhang, 2024).

Urban rivers serve as a means of communication between people and the natural environment. Designating a waterfront area as a monofunctional site seems out of place. The very character of the waterfront is denied by this area, and the city's residents seem unappealing. (Hradilová, 2012).

Water is a defining factor that shapes the personality of every site it comes into contact with. It is an aspect that should be honoured and celebrated rather than being viewed as a mere product (Mohamed, 2009).

2.3 Environmental Impact

Urban waterfronts have evolved into vibrant hubs of recreation and economic activity, and while historically driven by industrial growth, contemporary revitalization must prioritize environmental sustainability (Simons, 2023).

Rapid urbanization has degraded river ecosystems and reduced their ecological, aesthetic, and diversity value, making it essential to integrate rivers, waterfronts, and open spaces into resilient, interconnected recreational systems for urban well-being (Shrestha, 2019).

2.4 Flood Resilience

Urbanization alters stream hydrology by increasing runoff volume and speed, shortening concentration time, causing frequent flooding, and reducing base flow during dry periods due to decreased infiltration (Kalita, 2017).

Rivers are influenced by human activity in several ways, including construction on the bank, removal of riparian vegetation, and flow channelization. The river system's ability

to operate as a biotic system, customized to the physical features of that landscape, is constrained by these interventions. (Gole, 2013-2014).

2.4.1 Flood mitigation strategies

Green belts, or "blue-green infrastructure," are nature-based solutions that use vegetation to manage stormwater and mitigate flooding. They provide multiple environmental, social, and economic benefits (Global Facility for Disaster Reduction and Recovery, 2016).

Elevated walkways and promenades, built above the projected flood level, ensure that public access to the riverfront is maintained even during minor flood events. They keep pedestrians and cyclists safe (Climate-ADAPT, n.d).

Embankment walls, or levees and dikes, are conventional flood-control structures that protect high-value areas but are most effective when integrated with complementary strategies (Climate-ADAPT, n.d).

Floating and amphibious infrastructure provide adaptive solutions in flood-prone areas by rising and falling with water levels, allowing development to coexist with natural flood cycles (Barjatya, 2025).

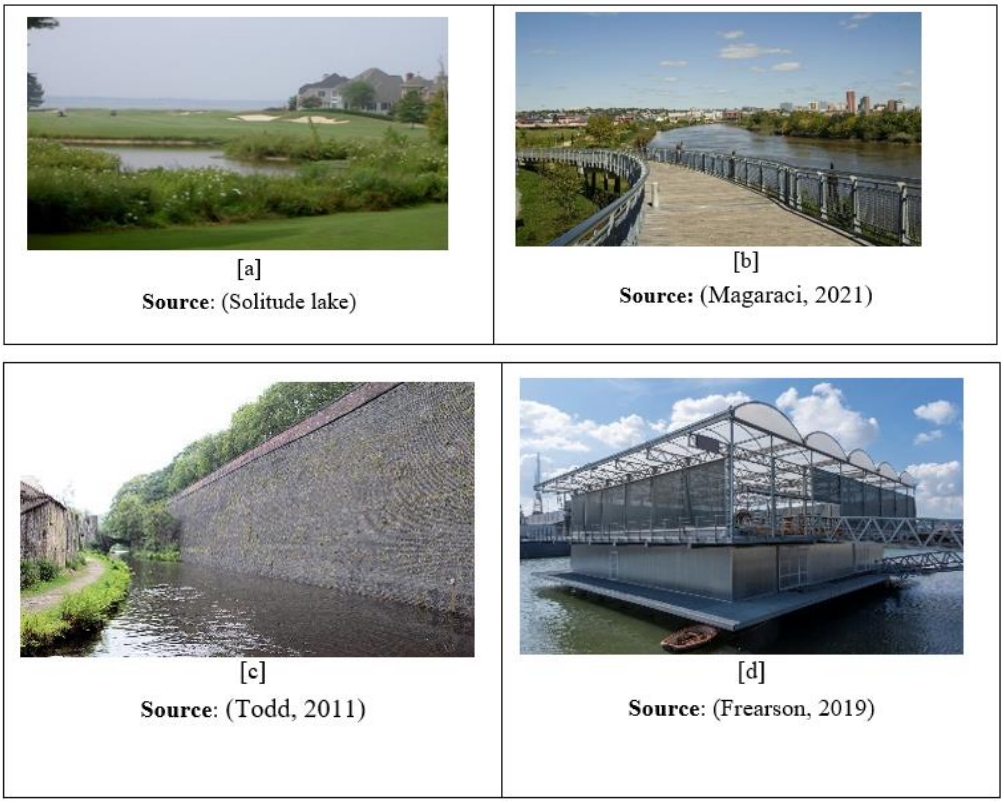


Figure 1. [a] Green belt/Buffer zone [b] Elevated walkways and platforms [c] Embankment walls [d] Floating or adaptable infrastructure

3. Methodology

This methodology employed a mixed-method approach, integrating qualitative and quantitative aspects. One method is about case study of existing riverfront projects – Sabarmati River front from India and the Thames riverfront from UK, to understand riverfront development character, features used, user interaction with the riverfront, the flood resilience strategies adopted and their integration in the development. Second method involves an online questionnaire survey aimed at exploring users' perspectives on the river's character and studying how they interact with the river edge.

The online Google Form was sent to 55 people, while valid responses obtained were 42, which made the final sample size with diverse age groups ranging from age 18 to 60. The form also focused on elements of flood resilience in the form of visuals. In addition, interviews were conducted with the residents of Pune staying near the riverfront, to understand their issues and concerns regarding the current condition of the riverfront. The questionnaire included 21 questions with multiple-choice and a 5-point Likert scale.

3.1 Sabarmati Riverfront Case Study

(Paneria, 2017)

Sabarmati Riverfront Development: Main objectives

- **Flood Mitigation:** Continuous retaining walls, embankments, and sluice gates regulate river flow and prevent seasonal flooding.
- **Environmental Restoration:** Improved water quality, ecosystem revival, and enhanced biodiversity.
- **Social Infrastructure:** Development of parks, promenades, cultural, and recreational public spaces.
- **Social Impact:** Enhanced community life through accessible spaces, events, employment, and social interaction.



[a]
Source: (Paneria, 2017)



[b]
Source: (Paneria, 2017)

Figure 2. [a] Sabarmati Riverfront [b] Raise walkway along the river

The Sabarmati riverfront features include:

The Atal Bridge for visual and physical connection, acting as a major attraction point offering views.

Amphitheatre, seating spaces and a continuous promenade along the river for walking and cycling.

Activities happening at the riverfront involve boat riding, cycling, walking along the promenade, cultural events like kite shows and a Sabarmati marathon.

The riverfront project implemented the use of retaining and embankment wall, man-made interventions, to tackle seasonal floods.

3.2 Thames Riverfront Case Study

(The History of South Bank in London: A Cultural and Architectural Evolution, 2024)

Main objectives

Accessibility & Connectivity: Continuous pedestrian routes and crossings ensure seamless, inclusive movement along and across the river.

Public Realm & Activity Diversity: A mix of leisure, cultural, and social activities creates vibrant, active riverfront spaces.

Inclusivity & Equity: Tension exists between open public access and privatized, commercialized waterfront zones.

Integrated Flood Risk Management: Combines engineered and nature-based solutions with adaptive, long-term planning. The features of Thames Riverfront include a continuous pedestrian pathway for walking, bridges and underpasses that ensure connectivity between both banks of the river.

The activities involve leisure walks, cycling, sitting along the embankment walls, cultural activities and dining. This caters to users with different age groups and lifestyles.

The riverfront uses the man-made measure, embankment walls, to manage floods with ecological features such as wetlands and floodable parks.



[a]

Source: (London cityscapes, 2013)



[b]

Source: (Vazhaeparambil, 2019)

Figure 3. [a] Thames Riverfront [b] Embankment wall along the river

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3.3 Analysis and findings of Questionnaire

The sample of 41 respondents was considered for analysis, including 5 males and 36 females belonging to different ages and income groups, as presented in fig. 1 and 2, respectively.



Figure 4. [a] Age of Respondents [b] Income of Respondents

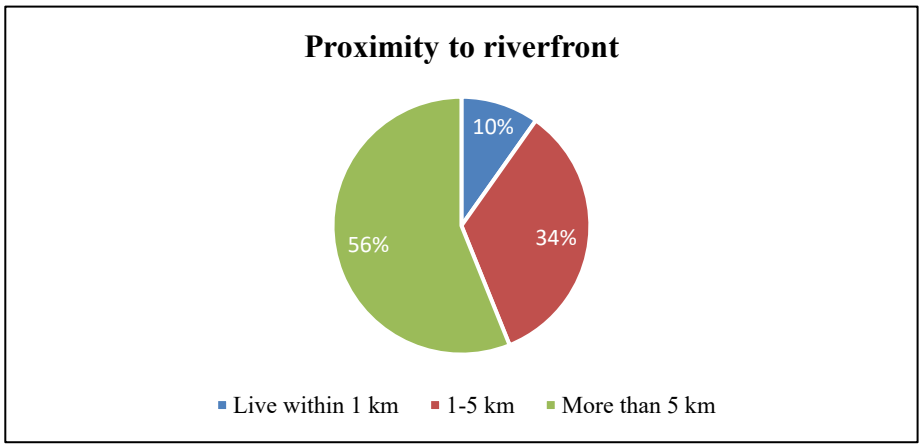


Figure 5. The Pie chart showing the proximity of residents to the riverfront

The age group followed 80% of the younger population [18-24], 5% each from 25-44 and 45-84. The family income of 74% is over 1 lakh, while 15% have 40k-60k, followed by 8% of 25k-40k and 3% up to 20k. **We can conclude that the riverfront is mostly used by the youth followed by middle aged population. Also, most of them are earning really well, which shows their spending capacity for activities which may be planned along the riverfront.**

56.1% of the respondents live more than 5km away from the riverfront, followed by 34.1% live 1-5km away and 9.8% live within 1 km of the riverfront. This shows that the river plays an important role in the life of the citizens of the city. **This also suggests that people from outlying areas are still engaged and affected by the riverfront development.**



Figure 6. The Pie chart showing the purpose of visiting the riverfront by the respondents

The most common purpose of visit is recreation and leisure, opted by 36% indicating that the riverfront is seen as a space for relaxation and enjoyment.
Cultural events and work/business accounts for 15% each, showing a community-centred usage and an individual work-oriented space.
Social gathering [12%] and commuting [7%] suggest the social and functional use of the riverfront.
A small share of respondents visits for multiple reasons, reflecting the riverfront's potential as a multipurpose public space.

The riverfront is mainly used for recreation and leisure, followed by exercise and commuting is given lesser importance. This indicates that people view the riverfront more as a space for relaxation and informal activities rather than formal, cultural, or commercial purposes.

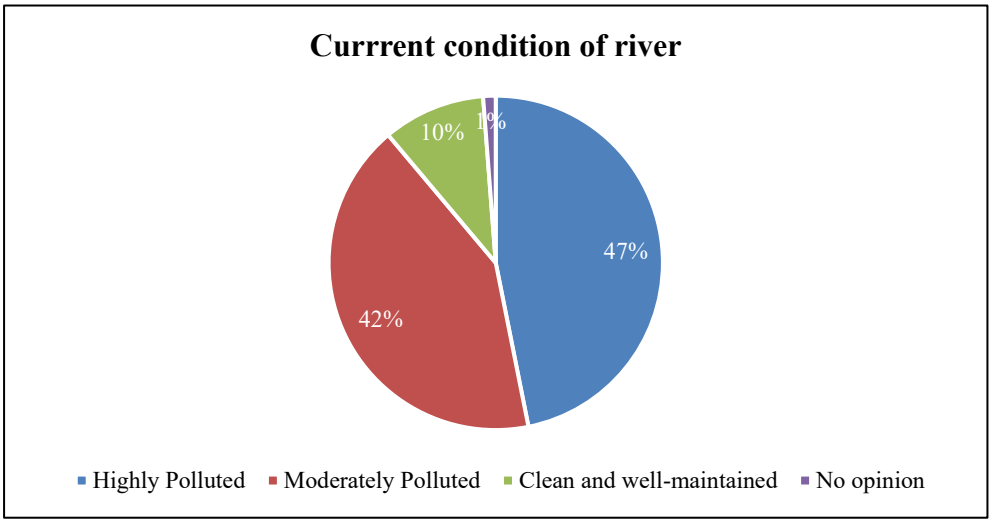


Figure 7. The Pie chart showing the people's view on the current condition of the river

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The current condition of the riverfront is expressed by 47% as highly polluted, followed by 42% saying it is moderately polluted, with only 10% describing it as clean and well-maintained**. The responses highlight a negative response towards the river's condition, reflecting users' dissatisfaction.**

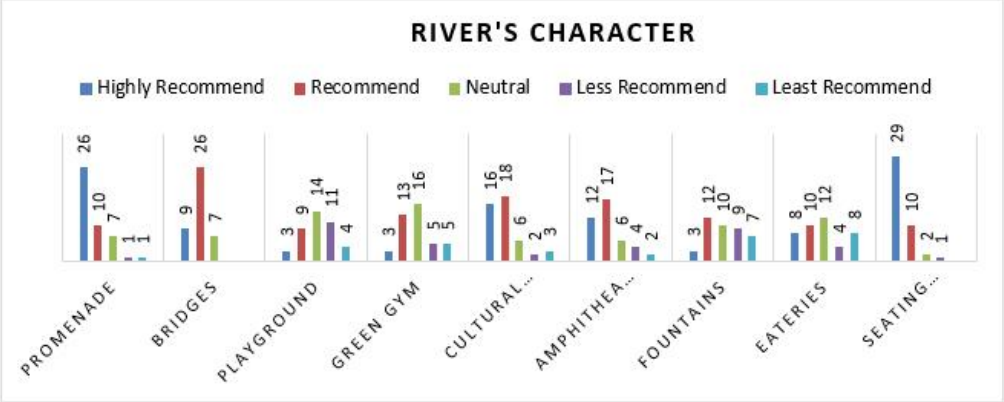


Figure 8. The graph shows people's preference on the character of riverfront development



Source: (Shah, 2016), (Manish, 2023), (Magaraci, 2021), (Outdoor Functional Fitness Gym Workout at Kansas City Park), (Julian B. Lane Riverfront Park) , (Furuto, 2012), (Hansen, 2020), (Riverfront Amphitheater in Fort Smith, 2010), (Henderson Riverfront), (Cultural Walking Tour Of Varanasi, 2018)

Figure 9. Different features of the riverfront

The survey shows that seating spaces and promenades are the most valued features for enhancing riverfront quality, followed by cultural landscapes and amphitheaters. Recreational elements like playgrounds, gyms, and fountains are seen as secondary, while bridges and eateries hold less importance

- Promenade and seating spaces are highly recommended along the riverfront, opted by 73% of the people, suggesting a strong interest towards activity-oriented spaces.

- Bridges and fountains are recommended by 60%, highlighting the interest in beautification of the riverfront.

- Amphitheatre and cultural landscape are less preferred by people despite Pune's strong cultural background, indicating their inclination towards more leisure and relaxing spaces.

- Green gyms, eateries and playgrounds received the least preference by people, reflecting the desire for more recreational spaces.

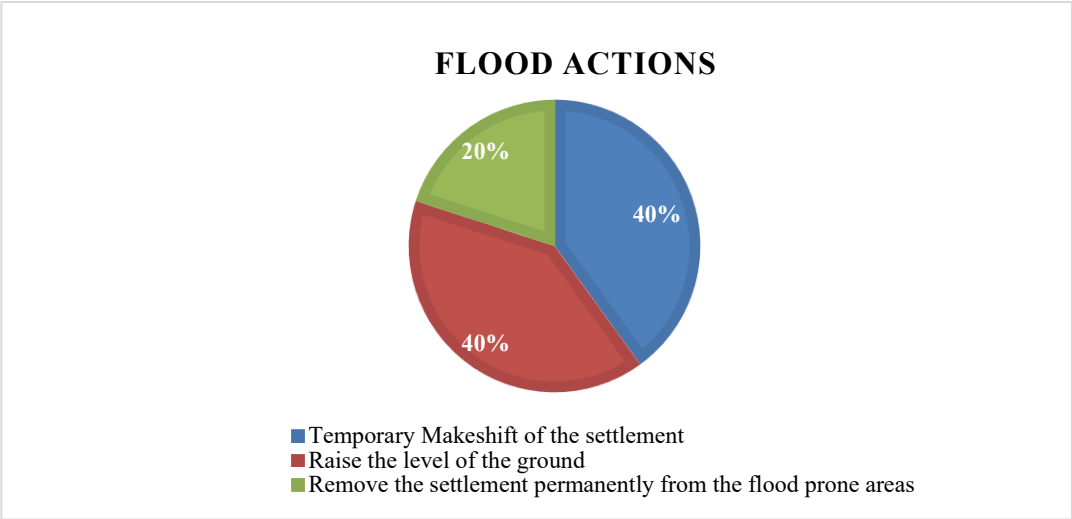


Figure 10. The pie chart represents the preferred flood actions by the respondents.

The preference for temporary makeshift solutions and raising ground levels shows that communities favor adaptive, in-place measures over permanent relocation. This reflects a need for resilience strategies that ensure safety while preserving social and cultural ties.

The interviews concluded that the current flood management measures taken for the riverfront involve the temporary makeshift of the settlement along the riverfront to a common building, suggesting the discomfort faced by people during the flood season. According to the survey, there was an equal preference for temporary shifting and raising the ground above as a safety measure, followed by a few people opting for the permanent removal of people living along the riverfront.

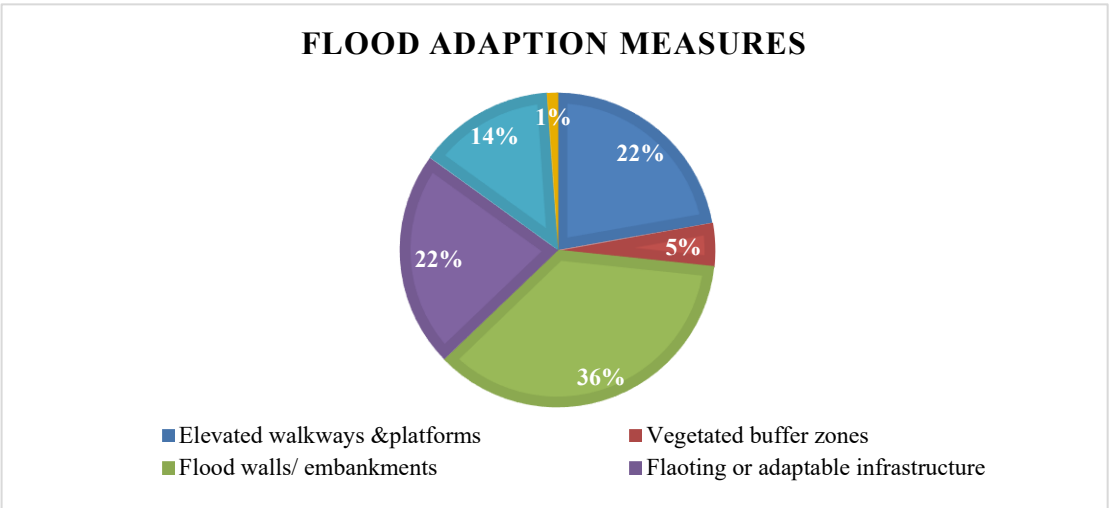


Figure 11. The pie chart represents the preferred flood adaptation measures by the respondents.

The chart indicates a distinct inclination among respondents toward structural and engineered flood management measures, such as embankments, retaining walls, and drainage systems. However, adaptive and ecological approaches—including wetlands, permeable landscapes, and green buffers—are gradually gaining recognition, though they remain less prioritized.

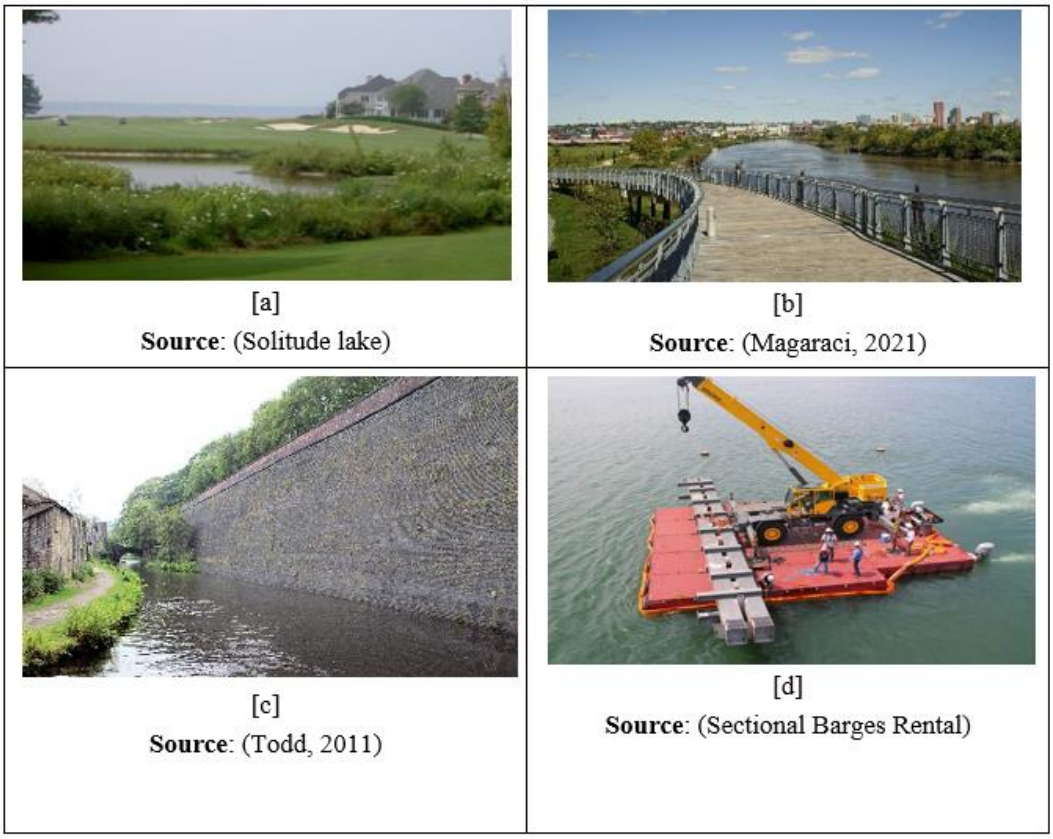


Figure 12. [a] Green belt/Buffer zone [b] Elevated walkways and platforms [c] Embankment walls [d] Floating or adaptable infrastructure

The survey showed the visuals related to the flood mitigation strategies, like- Elevated walkways, vegetated buffer zones, flood walls and adaptable infrastructure.

The user's preference was more towards embankment walls, a man-made preventive measure, followed by an equal suggestion for elevated walkways and adaptable infrastructure. Very few opted for vegetated buffer zones/green belts, suggesting less inclination towards ecological features.

Road as Commuter or not?

While many respondents find the roads along the river edge effective for commuting and should be kept as it is, but a need for the development of the river edge is expressed, suggesting the creation of public leisure spaces to sit, interact and relax.
Few people want the roads to be removed and completely turn them into a pedestrian pathway for a greater experience with recreational spaces along the riverfront.

3.4 Observational Study:

On-site visit to Mutha Riverfront, Pune to observe user behaviours, usage patterns, and infrastructure effectiveness. Documentation of public space utilization, maintenance, and environmental conditions.



Source: Google Maps
Figure 13. Area of study



Source: Authors (Field photographs, 2025)

Figure 14. [a]: Riverfront edges are used to hang washed clothes for drying [b] Garbage dumped along the river [c] Current condition of the riverfront [d] Shops setup along the riverfront

3.4 Issues and concerns that are surfaced from case studies and site interviews can be broadly classified under the following themes –

1. **Channelisation and Stagnant Flow**

The river's natural course has been altered through channelisation and embankments, causing silt accumulation, water stagnation, and ecological imbalance, diminishing the river's self-cleansing capacity.

2. **Pollution and Waste Disposal**

   Absence of proper waste management has turned the river into a dumping ground for household, industrial, and sewage waste. Continuous pollution has degraded water quality, making it unsafe and unusable for basic human activities.

3. **Lack of Flood Mitigation Measures**

   Insufficient embankments, drainage, and flood control systems leave nearby communities vulnerable to seasonal inundation. Frequent flooding damages property, disrupts livelihoods, and affects infrastructure.

4. **Displacement and Insecure Housing**

   Repeated flooding forces temporary relocation and loss of shelter. The lack of resilient, flood-adaptive housing exacerbates community vulnerability and social instability.

5. **Untreated sewage and Industrial Discharge**

   Unchecked industrial effluents dumped and untreated sewage have contaminated the river and groundwater, causing foul odour, discoloration, and loss of aesthetic and recreational value of the river.

3. Conclusion

Users –The study highlights that the riverfront is mainly used by the younger population, followed by the middle-aged group.

Riverfront features and user preferences

The survey and case study findings suggest that users primarily visualize the riverfront as a space for leisure, recreation, and visual appeal instead of cultural or commercial activities. The dominant features along with the riverfront include promenades and seating areas as a collective aspiration for activity-oriented yet visually attractive public spaces that encourage community interaction and connection with the river. Though commuting is on last priority, it is suggested by users that the road should not be removed but further developed with better facilities and amenities, adding to the user experience.

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Preferred activities suggested by the users along with the riverfront

According to user preferences, the riverfront is mainly used for recreational and leisure activities, followed by exercise, while commuting holds comparatively lesser significance. This indicates that people perceive the riverfront more as a place for relaxation and informal community interactions rather than for formal, cultural, or commercial uses. Enhancing infrastructure for recreation, walking, and social engagement could further strengthen its public appeal.

Problems during floods especially, faced by users using/staying near the riverfront

The interviews on site concluded that the current flood management measures taken for the riverfront involve the temporary relocation of the people, indicating the challenges faced by the users.

The user preferences to mitigate floods and increase flood resilience

The main preference for man-made interventions, embankment walls and elevated walkways, over the ecological measures, vegetated buffer zones/ green belts, suggests the importance of developing more integrated resilient flood mitigation strategies that ensure both safety and ecological sensitivity.

The users have also expressed concerns about the poor maintenance, limited accessibility towards the riverfront, lack of proper safety factors during floods, insufficient facilities and weak integration of ecological principles. These factors taken together have weakened the relationship between the users and the river edge, reducing the riverfront's value and potential as an inclusive and engaging recreational space.

From the perspective of flood resilience, implementing natural green buffers, adaptive landscaping, and ecologically sensitive urban design can help mitigate flood risks while enriching the environmental significance of the riverfront.

In conclusion, the results emphasize that the riverfront’s design should value accessible leisure zones, visual aesthetics, and comfortable public seating, in line with the community’s preference for a rejuvenating and user-centric urban riverfront. It also needs an integrated approach that maintains a balance within resilience, ecological sustainability, and user-friendliness.

Conflict of interest: The authors declare no conflict of interest.

AI Usage Disclosure

The authors acknowledge the use of artificial intelligence (AI) tools during the preparation of this paper. Specifically, ChatGPT (GPT-5) and Grammarly were utilised solely for grammar correction, language refinement, and minor structural improvements to enhance clarity and readability.

No part of the research content, analysis, interpretation, or conclusions was generated by AI. All core ideas, arguments, and findings presented in this paper are entirely the original work of the authors.

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TRACK 04

SUSTAINABLE AND LOW CARBON BUILT ENVIRONMENT



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Wetland Stream Restoration, A Pedagogical Approach in Environmental Science: A Case at Mutha Riverfront, Pune

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Abstract: Urbanization has caused the degradation of urban river edges. Urban river corridors are experiencing a decline in tree cover due to rapid real estate development. These areas serve as vital riparian zones, providing nutrients and ecological services to humans. This study examines the existing biodiversity, social impacts, and degradation of the riparian zone at a specific site as an environmental science studio outcome. It offers strategies for integrating ecological and social considerations to improve the riverbank. The objectives include identifying and mapping native vegetation, stabilizing banks through wetland stream restoration, with the student community as a part of the University curriculum. The methodology involves a case study, field assessments, and stakeholder interviews. Five pools were cleaned, lined with stone pitching, and the plantation and stream were channelized towards the river. Student exposure to real-world issues and possible solutions is facilitated through a hands-on workshop with field experts. This research presents a pedagogical approach to ecological parameters, including biodiversity mapping, riparian zone degradation, and wetland stream restoration. It showcases an example of a live Environmental Science studio used to teach ecological restoration through community involvement and collaborative efforts to address a real environmental problem. The workshop's outcomes included live problem-solving, raising awareness, and biodiversity documentation at the site, providing insights for future studies of similar river stretches. The study emphasizes the importance of community engagement and awareness, highlighting students' contributions to riparian zone management of urban rivers. It demonstrates how site-specific interventions can significantly improve the health of riverbanks. The research findings suggest that community and student participation, along with increased awareness, can solve practical issues through curriculum-based learning and hands-on solutions.

Keywords: degradation; river corridors; ecological services; biodiversity; hands-on workshop; riparian zone.

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1. Introduction

There is a contrast between the river's natural flow and the need for human interaction along its banks. Many city residents prefer neat, clean, manicured man-made landscapes and enjoy being near water for recreation. Water pollution, the treatment of rivers as dumping grounds, and loss of biodiversity pose serious threats, leading to lifeless rivers and ecologically sensitive urban riverbeds. (Lerner & Holt, 2012) The importance of learning beyond the classroom through action rather than just studying theory is demonstrated in this paper. Managing the current conditions of riverbanks requires long-term community involvement, a participatory approach, expert intervention, and holistic policies by local authorities to ensure the sustainable and healthy management of rivers. (Chou, 2016) This paper aims to examine the existing biodiversity and degradation of the riparian zone at a specific site and proposes strategies to incorporate ecological and social factors to improve the riverbank. The study's objectives include identifying and mapping native vegetation, stabilizing banks through wetland stream restoration, and engaging the student community. The research emphasizes community participation and awareness and highlights students' contributions to riparian zone management of urban rivers. Findings show that community and student involvement, along with increased awareness, can address practical issues through curriculum-based learning and practical solutions.

1.1 Significance of the study

Urban rivers face threats from pollution, land development, and altered hydrology. Riparian zones serve as transitional green buffer areas between urban developed regions and the river itself. (Gregory et al., 1991)These zones help control floods, regulate temperature, and protect habitats in city environments. (Naiman & Décamps, 1997) Rapid urban growth leads to the removal of trees and construction in flood zones, impacting their ecological functions. In many cities, these areas are often ignored, with unplanned restoration efforts that lack community, government support, and funding. Although there's an understanding of the importance of riparian zones and wetland restoration in theory, a gap still exists in their practical management and implementation. Many restoration projects overlook natural hydrological flows, public perception, and governance structures. (May, 2006) This research aims to present a case example of wetland restoration by combining student-led field studies, stakeholder perspectives, and the goal of providing a practical model for restoring wetland areas that support the ecological health of the river and promote social inclusivity.

When we think of a river, we usually see it as the only flowing water channel. However, it actually covers a large area that includes the riverbank, flood plains, wetlands, riparian zones of the lower water channel, and the upper levels—areas we often overlook. Therefore, when the river flows fully during the monsoon with its natural flow pattern, many structures built within the flood lines are affected, with rising water levels entering homes and streets. Stormwater management often fails due to the use of hard paved surfaces, fewer trees and roots to absorb

water, and low porosity. As a result, water attempts to infiltrate our homes. Every year, the so-called developed metros face severe flooding and destruction caused by the river. The government fails to address flooding issues proactively and instead responds by providing relief funds from taxpayers' money rather than implementing sustainable, long-term solutions. While the government cannot be solely blamed, our own actions also contribute, such as using toxic chemicals in our daily products and cleaners, and dumping domestic waste, which harm the river's ecology along with industrial waste. Urban development activities like construction, roads, and slums are altering riparian ecosystems. Hence, there is a need for spatial mapping to identify vulnerable river edge zones or those that are degraded.

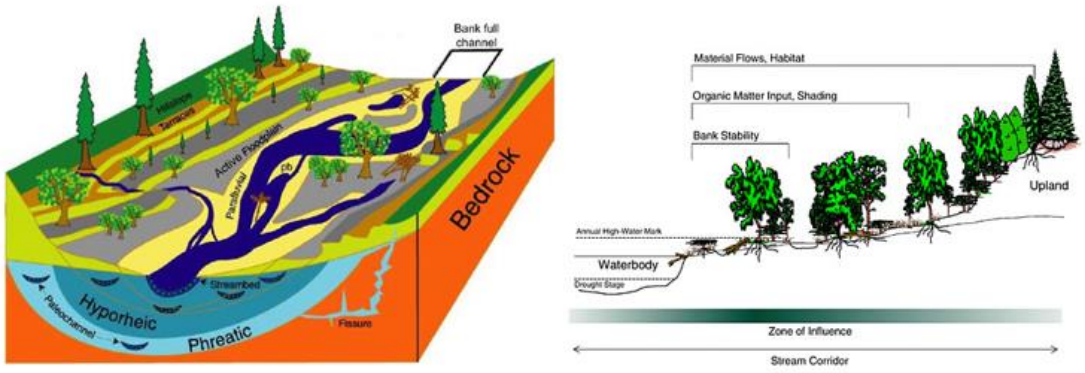
2. Literature Review

2.1 Wetland

Wetlands are semi-aquatic areas, meaning land is submerged underwater either year-round, seasonally, for decades, or permanently. These zones act as transitional areas between the main river and dry lands and support independent ecosystems due to their vegetation rooted in waterlogged soil. (Campbell D, 2020) With the Ramsar Convention, many wetlands and waterbody conservation efforts have gained momentum.

2.2 Riparian Zones and Urban River Health

Riparian zones are ecological areas crucial for maintaining river ecosystem services, including sediment filtration, nutrient retention, erosion control, and habitat connectivity (Naiman & Décamps, 1997). In urban contexts, these zones are often limited by land development, leading to ecological simplification and hydrological disconnection (Walsh et al., 2005). Research indicates that even narrow, vegetated buffers can significantly enhance water quality and bank stability in urban streams (Mayer et al., 2007).



(a) (b)

Figure 1. River structure (a)Idealized view of an alluvial river corridor (b) River riparian green corridor (Source: National Academies of Sciences, Engineering, and Medicine.)

2.3 Restoration Strategies and Techniques

Globally, riparian restoration strategies have shifted from structural, engineering-focused methods to more ecologically based, nature-driven solutions. Bioengineering techniques using native vegetation, coir logs, and brush layering have been effectively used to control bank erosion and improve habitat quality (Gray & Sotir, 1996). However, their use in densely urbanized areas—especially in developing countries like India—remains under-studied.

2.4 Pune and the Mutha River

Pune is a growing urban centre in Maharashtra next to Mumbai. Referring to the Mutha River flowing through the heart of Pune would be a wrong connotation. It is rather Pune, which was a small town born beside the Mutha River, dependent on it for water requirements and cultural activities besides it. Due to its expanse today, it seems the river flows through it. There are projects which are in place, such as the Pune River Rejuvenation Plan and Smart city interventions, but lacking site-specific community-driven efforts.

2.4.1 Story of Mula-Mutha River

The Mula-Mutha River in Pune, Maharashtra, has a rich local legend. The story of the Mula and Mutha rivers being sisters is a captivating local myth. According to the legend, the rivers Mula and Mutha were once divine sisters, each with its own unique personality. Mula, the older sister, was known for her calm and nurturing nature, symbolizing stability and nourishment. Mutha, the younger, was lively and energetic, representing vitality and change.

The sisters were believed to descend from the heavens to bless the region with their life-giving waters, bringing fertility to the land and prosperity to its people. However, like many siblings, they had their disagreements. Their paths diverged at times, but eventually, they reunited, merging in a symbolic act of harmony and unity. Their confluence, where the two rivers meet, is considered a sacred and spiritual site, symbolizing the balance of opposing forces. (Chikerur A, Natekar P)

It's believed that the meeting of the Mula and Mutha rivers carries great spiritual significance, and many myths link the rivers to divine blessings. A well-known story describes the rivers as gifts of life and prosperity from the gods to the people in the region.

2.4.2 Origin of the river

These rivers originate near the Sahyadri Hills, where many tributaries merge their waters and begin their journey toward the plains. The Mutha River starts at a dam near the village of Temghar, fed by catchment areas in the surrounding hills. Its source is in Vegre, a town in the Western Ghats, which is lush with herbs and plants. The river begins in the mountains, rich in forests and natural springs, providing fresh, clean water. Rainfall helps refill the river, ensuring it continues flowing. The water is dammed at Temghar and Khadakwasla. "The name of the river comes from the word *Muthai,* for 'Mother Mutha' in Marathi. This is from the local shepherd community, which resides in the source region. Small crabs resemble a closed fist. In

Marathi, the closed fist is called "*Muth"*, as mentioned by Shailaja Deshpande, director of the Jeevitnadi-Living River Foundation. Meanwhile, the Mula River emerges from the Mulshi Dam, built along its course to regulate its flow. Their confluence marks a significant cultural and ecological point in Pune, and the combined river flows eastward to merge with the Bhima River, a tributary of the mighty Krishna River. (Chikerur A, Natekar P).

3. Method

The objective was to assess the current condition of riparian vegetation along a particular stretch of the Mutha River. The methodology encompasses a case study, ecological field assessments, field surveys (including species composition and canopy cover), baseline data collection, interviews, pilot projects, and community engagement**.** Baseline understanding of hydrological and riparian zone status through photographs and videos. **Field Assessments of Vegetation Surveys**: Species inventory, cover, diversity, and structure of shrubs/trees. Biodiversity mapping was conducted by documenting photos on site, marking flora in maps and plans, describing the flora supported by pictures. So, the method used for mapping biodiversity was through transect walk method from river edge to road edge marking, vegetation zones, animal presence on base maps through sketches, photos and annotations. Thus, invasive species, native, aquatic, indicative species and riparian vegetation was identified and documented. Mobile applications such as I Naturalist and eBird were used to document data online. Behavioural observation and fauna sightings of insects and birds was done such as to understand their feeding areas and nesting area. Workshops for participatory mapping, existing condition, biodiversity, and restoration co-design were conducted for students. Stakeholder engagement strategies with a student-driven educational model for riparian zone maintenance and monitoring through clean-up drives and awareness programs. A participatory mapping workshop was conducted with students and experts towards riparian stewardship, as shown in **Figure 2.**

Lecture delivery by experts as an orientation, followed by two extensive days on field data collection on the flora and fauna, river edge condition, cultural and religious surrounding buildings, was conducted. The experts delivered a lecture on-site to the students for two days to map the biodiversity and the wetland restoration techniques to be adopted on-site, which helped students to conduct the survey.



(a) (b)

Figure 2. Interaction with Experts from Jeevitnadi to understand the site (a) Orientation workshop by the Jeevitnadi team (b) SY B.Arch. Students with the Jeevitnadi team

4. Case study- Description of the case

4.1 Study Area Selection

The selected case is a stretch located at Vitthalwadi, Sinhgad Road, on the eastern banks of the Mutha River, Pune city. The adjacent areas have religious ritual sites such as two temples and a cemetery, as indicated in Figure 3. The site can be accessed with a few steps from a road. One small *Mahadev* Pundalik temple is within the river bed where a fresh water live spring, *Gomukh* (Cow head stone water spout), is present, which is a traditional stream conservation practice in India. These two sites often get flooded in monsoon when the river flows in full swing and the water level rises, reaching the road level, submerging the *Mahadev* Temple. (Deodhar A etal, 2018). The actual river width is 140 m, but after the concrete embankment, it is 30m (Oikos, 2021)

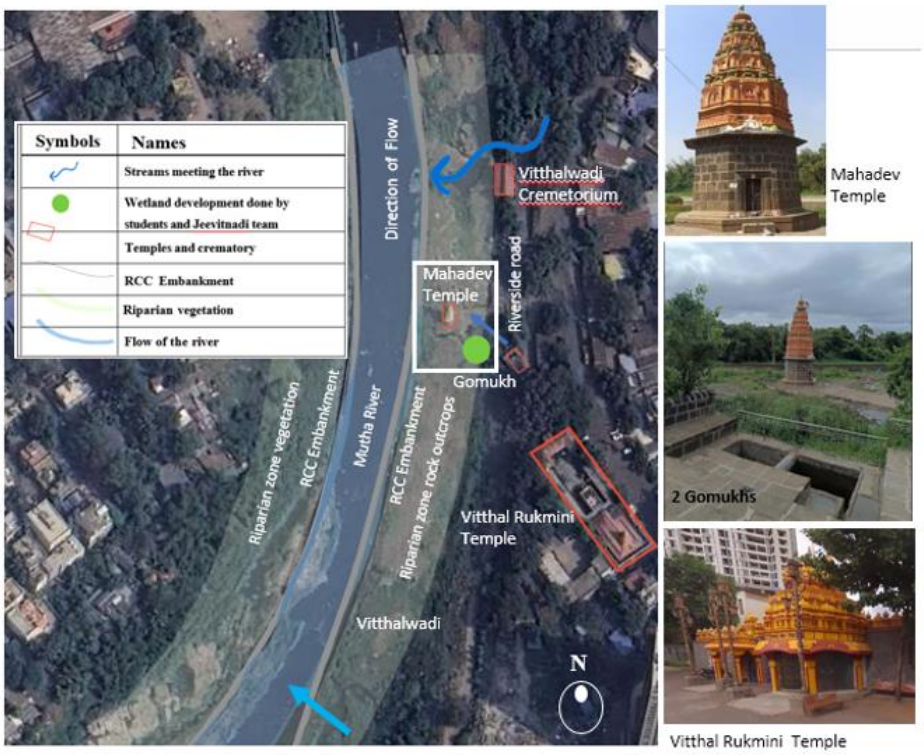


Figure 3. Google map showing the study area and important religious sites, *Gomukh* freshwater, documented by ACWADAM.

4.2 Ecological relevance

The area at Vitthalwadi is characterized as a rocky habitat, featuring potholes, rock crevices, and soil or sand between rocky boulders. There are potholes, a geological feature formed over time, on the eastern bank. These are habitats for small fish, grasshoppers, and other aquatic insects. The dominant microhabitats at Vitthalwadi are aquatic, marshy, and rocky with potholes (Kalamkar U et al, 2024). Since the Mutha River is seasonal, the wetlands are also seasonal. The Vitthalwadi section of the Mutha River has two types of wetlands -

Flood plains: These are areas that allow river water to spread out during heavy rains, preventing flooding. They also support the growth of aquatic plants, algae, grasses, shrubs, and more. These areas help protect nearby settlements from floodwaters.

Riparian zones: These are areas where the land is quite marshy or the ecosystem is adapted to waterlogged conditions. A rise in species richness was observed at Vitthalwawdi, attributed to the diverse microhabitats along the riverbank. Ottelia alismoides (Duck Lettuce) was recorded from a very specific habitat with a basaltic rocky area with potholes filled with water. (Kalamkar U etal, 2024) Figure 5 indicates the cross-section of the river bed.

4.3 Cultural Relevance

Religious Rituals: Devotees perform pujas and ceremonies near the river, which also has a cemetery. *Warkaris* visit and stop by every year during *Waari.* Historical Significance: The temple's location reflects Pune's cultural heritage. Geographical Impact: The river influenced settlement patterns. Sacred Connection: The Mutha River is considered holy, boosting the temple's spiritual importance.

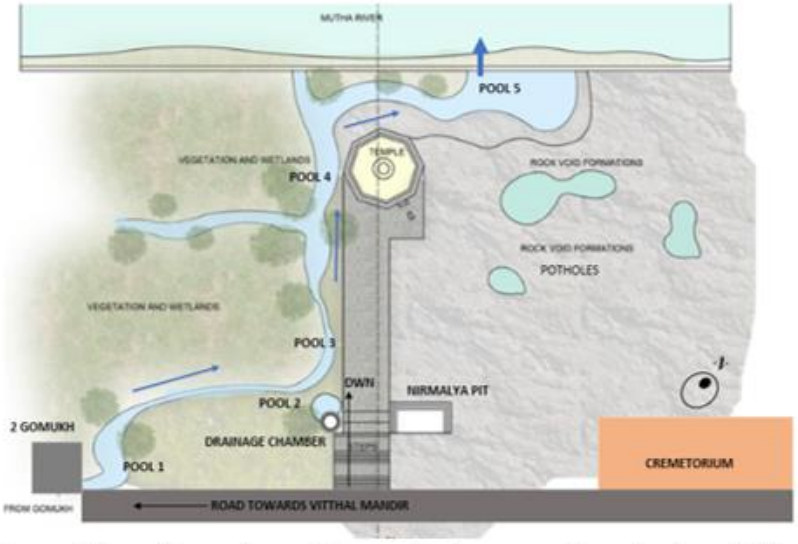


Figure 4. Plan of the study area (Source: Student report, drawn by Aayan Mulani)

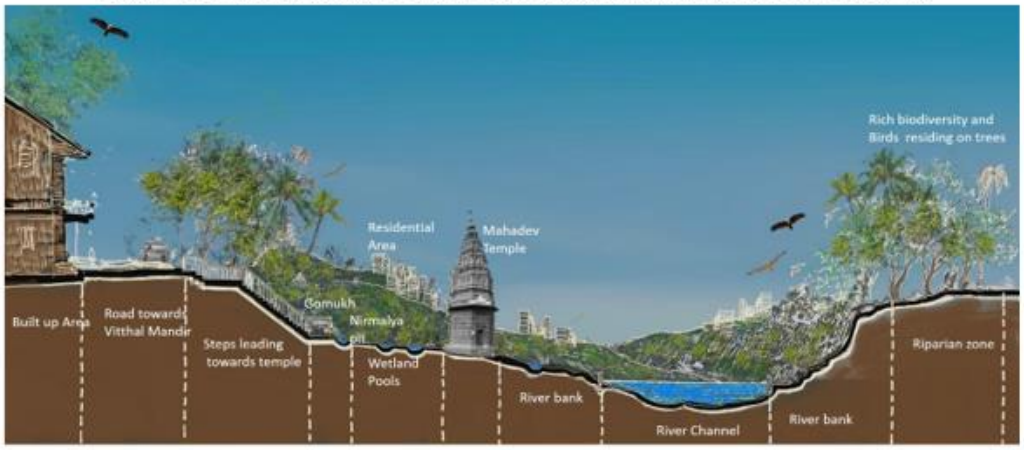


Figure 5. Section AA' from the main steps leading to the river and the small temple. (Source: Author)





Figure 6. Multiple freshwater sources feed the river **Figure 7.** RCC Embankment by the local body

4.4 Present Condition

4.4.1 Pollution & Contamination due to human activities

Environmental Aspect: Pollution affects the river and its surroundings. Sewage Dumping: A large volume of untreated wastewater from homes and businesses flows into the river. Industrial Waste: Factories discharge chemicals and pollutants, making the water unsafe. Garbage & Plastic Waste: People throw trash into the river, worsening its condition. Deforestation & Soil Erosion: Cutting down trees near the river causes soil to wash into the water, making it dirty. People wash clothes and bathe at the *Gomukh,* and cattle are also brought for grazing. The river is subject to religious festival activities like Ganesh idol immersion, *ghatsthapana*/ *kalashsthapana* immersion in Navratri. Local boys visit the river for fishing. The river is heavily polluted and not safe for drinking or even for aquatic life. It has been classified as "severely polluted" by environmental authorities. Wetlands used as a dumping ground: People of the city throw garbage and also the flowers' '*nirmalya*,' as it is adjacent to the temple, and are discarded without a second thought. Clean-up projects are ongoing, but more efforts are necessary. Drainage Water: Untreated drainage water is directly discharged into the river, leading to contamination and ecological disturbance.

4.4.2 Major threat - Embankment on the edge of the river

Concretization on riverbanks, as shown in Figure 7, due to projects like riverfront development, has severely impacted the groundwater table, as water cannot percolate through the concrete. The groundwater table is significantly impacted because water cannot seep through the concrete. (Nulkar et al., 2021) Due to the embankment, the contact between river water, wetlands, riparian zones, and the actual river pool is interrupted. As a result, the wetland ecosystem is affected. Additionally, introducing exotic plant species disrupts the habitat because animals that rely on native trees cannot adapt to the exotic ones.

5. Findings

5.1 Biodiversity mapping

The students were given tasks in groups on-site based on the kind of data collection, awareness, cleaning, and documentation through photos, videos, and surveys. The Biodiversity Mapping Group focused on documenting the stream's flow, identifying different types of grasses and shrubs, and noting sightings of various bird species. This exercise helped them realize the diversity of life that depends on a healthy river ecosystem. A significant amount of plastic waste was removed from the area. It was truly eye-opening to see how much can be accomplished when a group of people unite with a common purpose. The visit not only expanded students' knowledge but also left them with a sense of pride and responsibility toward conserving our natural resources for the future. The Painting Group worked on awareness-raising art, creating beautiful visuals that emphasized the importance of river conservation and the urgent need to protect our natural water bodies.

Creating divergent channels – a pond network for flood waters. It is believed that water from *Gomukh* and other freshwater springs comes from Sinhgad Fort, as shown in Figure 6; it flows continuously throughout the year. The water quality of these three springs has been tested by the Advanced Centre for Water Resources and Management (ACWADAM) and has been declared as freshwater. (Kulkarni, 2022) But due to interventions such as concrete embankment and laying of drainage pipeline adjacent to the river bed on the eastern roadside, the natural stream water is blocked and doesn't reach the river. There are many pools found in this rocky terrain, but due to drainage leakage, it sticks and is not an inviting space for visitors or devotees. In 2018, earlier work of stream restoration was carried out, and pools were created, but again, it needed blockage removal. The pools along the stream were numbered from 1 to 5, and mile stones were painted, making it easier to monitor changes and progress. So, the Restoration Group took the lead in clearing the stream path by removing unwanted grass and stones. Thus, creating pathways for the freshwater stream from '*Gomukh*', towards the river will feed fresh water to it, as shown in Plan figure 4. Students formed a human chain and carefully arranged stones and the border to create a natural flow for the stream toward the river. So, small pond-like structures were made by arranging stones to connect the streams to the river. Five pools were enhanced, and the stream was channelized with natural edges made of stones from the same site. The aim was to restore river hydrology and biodiversity. The natural flow of the stream was restored. To improve water quality, *Jeevamrut* was mixed, and the water quality will be tested. *Gomutra* will aid good bacteria in the 1st pool of the stream. Objective of the Restoration of the Stream. The objective was to increase infiltration, slow down run off, and create habitats.

3.1.1 Vegetation Assessment

Flora refers to the plant life of a specific region, habitat, or period, including native, cultivated, and wild species. Biodiversity mapping aims to identify the type of plant or tree, its scientific name, and whether it is naturally grown or was introduced and is now starting to grow. Riparian

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vegetation on the bank of the river was documented to understand species composition, native vs. invasive cover**.** If it is non-native, it is often not a desirable plant—probably a weed or parasite that steals nutrients from native plants. Bigger trees on the western bank act as a nesting roosting site for birds.

This vegetation belt attracts diverse fauna and acts as a buffer. For example, Indian Willow (*Walunj*) is one of the most commonly found species along the riverbank of the Mutha River and serves as an indicator of a healthy, clean habitat. A few others are *Umbar,* Ficus, Salix Tetrasperma (*Walunj*), *Karanj*, Babul, etc. Duckweed helps purify water; the streams flowing from the duckweed ponds were so clean that small fish and water striders were seen in the marshy areas further downstream. Many herbs and medicinal plants are cultivated near the river, but their growth rates have also declined. The figure 8 highlights specific patches where certain plant species were notably present. While the land supported a diverse range of vegetation, the mapping emphasizes areas where particular species appeared in significant concentrations. Figures 9 and 12 provide detailed information on the species.

3.1.2 Faunal analysis

Due to the embankment, the contact of river water between the Wetlands 2 riparian zones and the two actual pools of the river is cut off. Thus, the wetland ecosystem is disturbed. Many species of shrubs and birds that live on the leaves of the lotuses, such as Phesant-tailed Jacana, have gone extinct because of the embankments. Perched herons, painted storks, black herons, Butterflies, dragonflies, frogs, crabs, kingfisher, mongoose, black kite, green pigeon (*Hariyal*), Maharashtra's state bird. etc. are documented through photographs as shown below in Figure 9. These species indicate better habitat quality- Pied kingfisher, River tern, little ringed plover, and *Hariyal*. The wetland and river site are a habitat for butterflies, reptiles, a perching site for open-billed and painted stork, a roosting site for crabs and dragonflies, fish, and frogs.

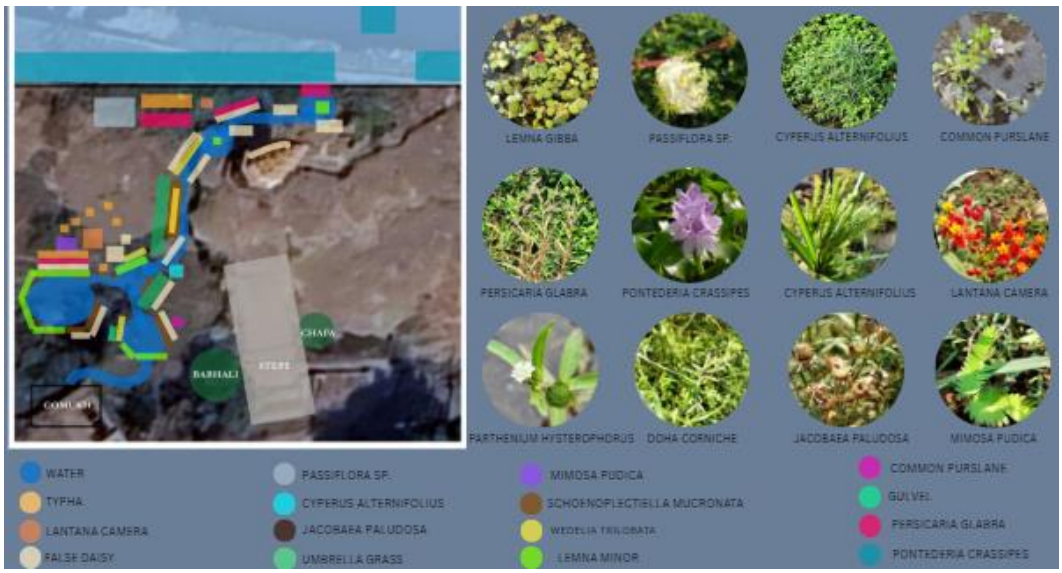


Figure 8. Locations of Flora around the wetland stream
(Source: Chinmaye Khatal, SY BArch Student)

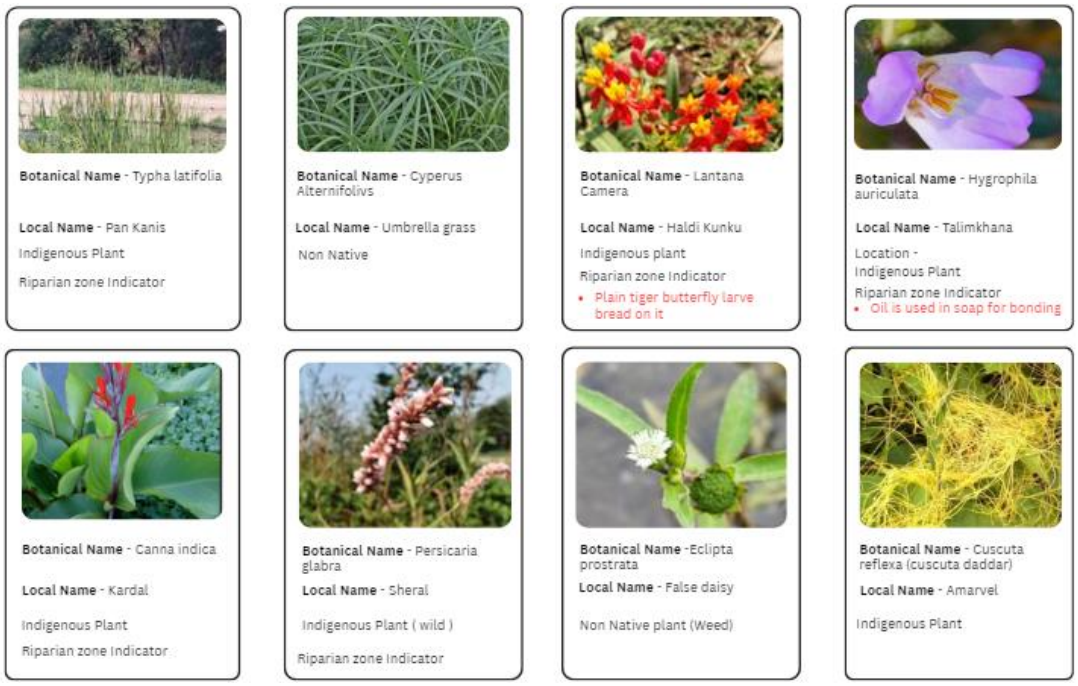


Figure 9. Information provided to Students by Jeevitnadi expert Mrs. Archana Mirashi
Source: Aarya Jagtap

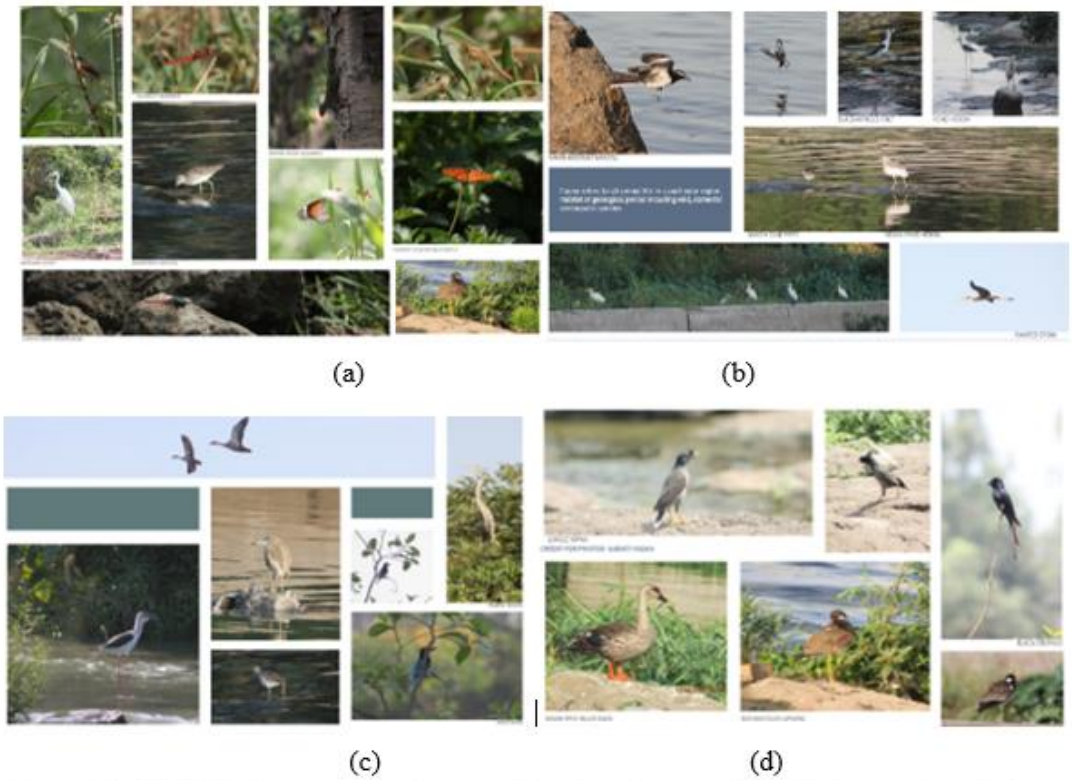


Figure 10. *(a) Birds, insects, animals around the riparian zone (b) Birds interacting with water (c) Birds on the trees Source Shravani Natuskar (d) Ducks, birds at the river. Source Ashwini Bhilare-Patil.*

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(a) (b)



(c)

Figure 11. Before and after work done by students (a) Awareness painting work done on the Drainage chamber that there is a wetland stream restoration project done, and grass removal (b) stone pitching around pools and stream (c) Stream flow channelization, removal of debris, and grass from pools



Figure 12. Group work of students engaged in restoration, garbage collection, painting, and listening to the Jeevitnadi team experts during the Environmental Science Subject workshop

4. Discussion

Students learnt through direct experience, interdisciplinary learning engaging with community. Qualitative Case study and context specific issues and solutions were provided. Collaborative learning with peers, experts, residents enhancing team efforts and environmental responsibility as an individual. Being architecture students they got involved in inquiry driven field-based investigations of biodiversity to understand spatial considerations of zoning and development besides riverbank. Ecological literacy beyond classroom theory was experienced by doing on live site. Thus sustainable design thought process is triggered to respond in an ecological sensitive area. Thus, the pedagogy of the studio was to connect the dots between architectural approaches and design thinking process within a sensitive urban environment. This in-depth field-based case study presents a methodology to study Environmental Studio's one group assignment for undergraduate Architecture student, for biodiversity assessment as the core learning outcome.

5. Conclusion

Incorporating nature-based solutions (NBS) instead of traditional engineering methods like concrete embankments can address issues such as flooding and garbage. Asking what the river wants will guide us forward, rather than diverting its natural course. Conserving and enhancing existing Biodiversity corridors and connecting the fragmented riparian zones along both riverbanks across the city is necessary. Therefore, Jeevitnadi proposes adopting sections of the river by local communities in each area to safeguard, protect, and nurture these zones. Consistent seasonal monitoring of the river edges throughout the year will help us understand

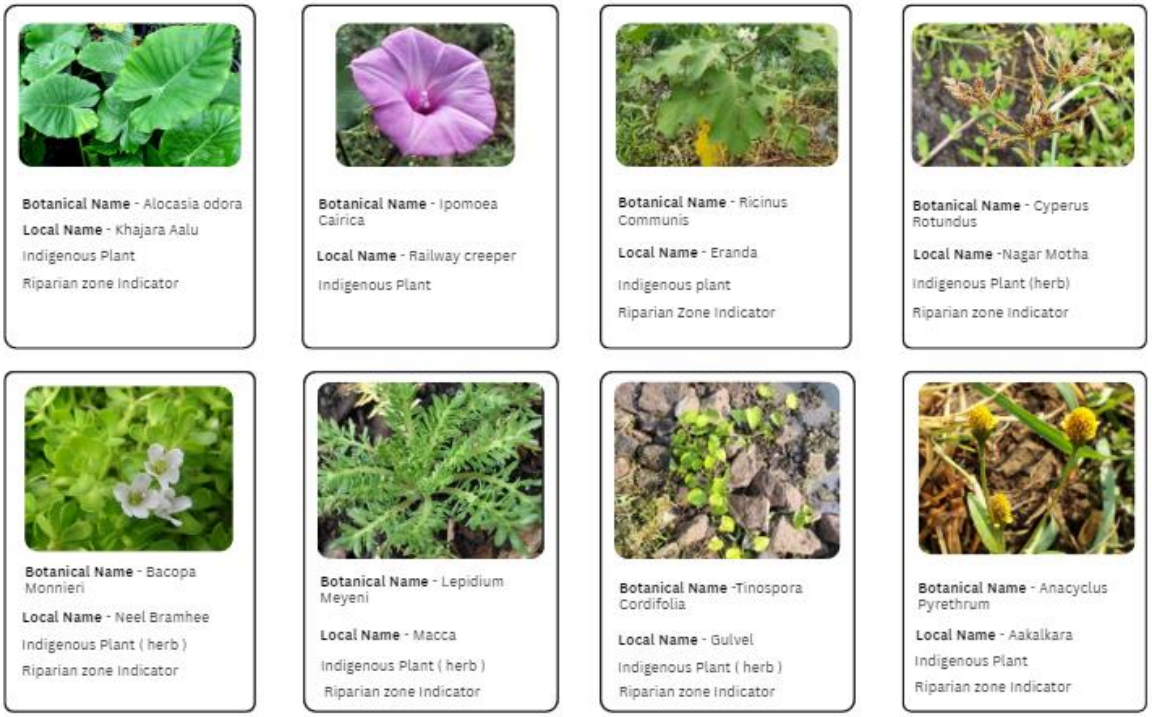
the river and the surrounding natural landscape, maintaining a balance between ecological health and community wellbeing. If community engagement efforts are consistent, they can lead to the long-term success of urban river restoration projects. Community-based riparian stewardship and awareness programs can support sustainable river restoration. Multiple stakeholders, including experts in hydrology, geology, landscape architecture, planning, botany, ecology, and environmental engineering, need to collaborate. Gaining understanding from local communities about their perceptions and participation in ecological conservation of the river development projects proposed by the local government is essential. Urban river health can be monitored using tools such as remote sensing, GIS, and drone photography to assess the current situation. Digital reporting tools are available to record data from anywhere in the world, including geotagged photographs and numerical data.

Community-centered ecological planning with local stewardship in riverfront development is necessary, rather than just beautification through concrete viewing decks. Zoning along the edges to physically demarcate access to the river—allowing for viewing and no-access zones with riparian zone conservation—would be the best solution and a win-win situation that promotes an environmental stewardship approach. Students, volunteers, and motivated young people can serve as a strong force to bring about positive change.

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Conflicts of Interest: "The authors declare no conflict of interest."

Appendix



(a)

Figure 11. Shrubs' pictures were clicked during the workshop by SY B.Arch. students classified according to native or non-native and good or bad indicator of riparian zone, (a) Photo pallets of flora, (b) Description of flora. Source: Chinmayee Khatal, Shravani Utpat, **Source:** Aarti Yadav

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Integrating India's Green Ratings: A Comparative Study of IGBC and GRIHA

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Abstract: India's construction sector is one of the fastest-growing contributors to national energy consumption, resource depletion, and environmental degradation. In response, green building rating systems have emerged as critical instruments to promote sustainable design, construction, and operation of buildings. Among these, the Indian Green Building Council (IGBC) and the Green Rating for Integrated Habitat Assessment (GRIHA) are the two most widely adopted frameworks in India. While both aim to reduce environmental impact and improve building performance, their parallel evolution has resulted in overlaps, methodological differences, and limited comparability of outcomes. This research presents an in-depth comparative analysis of IGBC and GRIHA, supported by detailed case studies of certified buildings to address the limitation of purely conceptual evaluation. The study examines six core sustainability parameters: energy efficiency, water management, material and waste management, indoor environmental quality, site and ecological planning, and socio-economic considerations. Two institutional buildings—one IGBC-certified private campus and one GRIHA-certified government building—are analyzed to understand how rating criteria translate into real-world design decisions and operational performance. The findings reveal that IGBC's flexible, market-driven structure enables rapid adoption and innovation, particularly in the private sector, while GRIHA's performance-based and climate-responsive approach ensures stronger alignment with India's environmental policies and long-term sustainability goals. However, both systems exhibit limitations in post-occupancy performance monitoring and unified national benchmarking. The paper proposes an integrated framework that combines IGBC's adaptability with GRIHA's scientific rigor, offering a more coherent, accountable, and context-sensitive pathway for sustainable development in India's built environment.

Keywords: IGBC, GRIHA, Green Building Rating Systems, Sustainable Architecture, Case Study Analysis, Indian Built Environment.

1.Introduction

Background

India's urban transformation represents one of the most significant spatial expansions in the 21st century.

The building sector accounts for approximately 35–40% of total electricity consumption and nearly one-third of greenhouse gas emissions when including embodied energy in materials. With increasing cooling demand due to climate change and economic growth, energy consumption in buildings is expected to triple by 2050.

Traditional building practices in India historically demonstrated climate responsiveness courtyards, shading devices, thermal mass, and natural ventilation. However, contemporary urban construction has increasingly adopted energy-intensive glass façades and mechanical

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cooling systems, leading to: Urban heat island intensification, High operational energy demand, Indoor environmental discomfort, Increased carbon footprint.

India stands at a critical juncture of urban and architectural transformation. With more than 35% of its population residing in urban areas a figure projected to rise steadily, the demand for housing, commercial spaces, and public infrastructure is increasing rapidly. The construction sector, while acting as a key driver of economic growth, is also one of the largest consumers of energy, water, and raw materials. Conventional building practices often neglect environmental considerations, leading to inefficient energy use, excessive water consumption, and poor indoor environmental quality.

The concept of green buildings emerged as a response to these challenges, emphasizing resource efficiency, reducing environmental impact, and improved occupant well-being. Green buildings aim to minimize negative effects on the environment throughout a building's life cycle from planning and design to construction, operation, and eventual demolition. To evaluate and encourage such practices, green building rating systems were developed globally. In India, IGBC and GRIHA have played a pivotal role in shaping sustainable architectural practices. However, despite similar objectives, the two systems differ significantly in philosophy, assessment criteria, and implementation mechanisms. Architects, developers, and policymakers often face uncertainty in choosing between them, while researchers find difficult to compare outcomes due to the absence of a common benchmark. This paper seeks to address these issues through a comprehensive comparative and case-based study of IGBC and GRIHA.

Problem Statement

Despite similar sustainability objectives, IGBC and GRIHA:

- Operate independently
- Use different weighting systems
- Apply varied performance validation mechanisms
- Produce non-comparable rating outcomes
- This fragmentation creates:
- Policy inefficiencies
- Confusion among architects and developers
- Lack of unified national carbon accounting
- Limited longitudinal performance verification

1.1 Research Questions

How do IGBC and GRIHA differ philosophically, institutionally, and technically?
What measurable environmental performance outcomes result from each system?
How effectively do rating criteria translate into operational performance?
Can an integrated national green building framework enhance sustainability outcomes?

1.2 Theoretical Foundations of Sustainable Architecture

Sustainable architecture integrates:
- Environmental sustainability
- Economic feasibility
- Social equity

Theoretical frameworks include:
- Ecological modernization theory
- Institutional governance theory
- Life-cycle assessment (LCA)
- Climate-responsive design theory

GRIHA aligns closely with ecological modernization, embedding regulatory oversight. IGBC aligns with market transformation theory, encouraging voluntary sustainability adoption.

1.3Global Green Building Systems

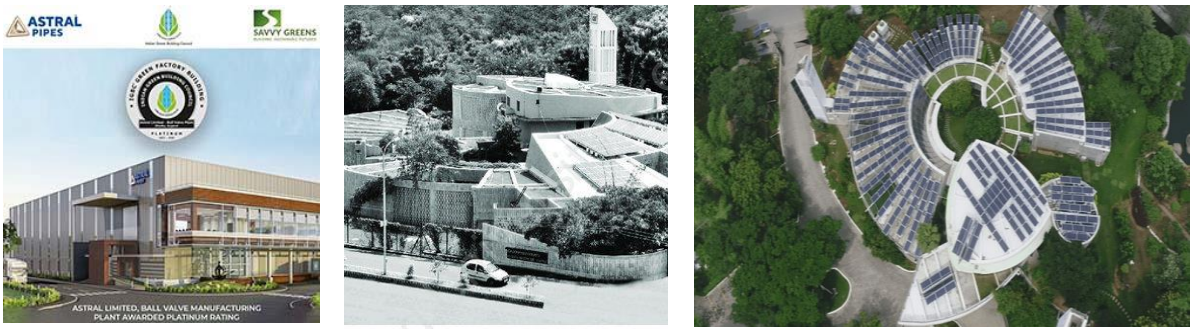
Globally influential systems include:
- LEED (USA)
- BREEAM (UK)
- Green Star (Australia)
- IGBC draws methodological inspiration from LEED, whereas GRIHA is more context-specific and policy-aligned.

2.Evolution of Green Building Rating Systems in India

The green building movement in India gained momentum in the early 2000s, influenced by global sustainability agendas and increasing awareness of climate change. The Indian Green Building Council (IGBC) was established in 2001 by the Confederation of Indian Industry (CII) as a voluntary, market-oriented rating system. Adapted from the U.S. LEED framework, IGBC was customized to suit Indian climatic conditions and construction practices. Its flexible structure and multiple rating variants—such as Green Homes, Green Factories, and Net Zero Buildings enabled widespread adoption, particularly in the private sector.

Recognizing the need for a nationally contextual and scientifically grounded system, The Energy and Resources Institute (TERI), in collaboration with the Ministry of New and Renewable Energy (MNRE), introduced GRIHA. Officially adopted as India's national green building rating system, Reemphasizes performance-based assessment, climate responsiveness, and alignment with government policies. Unlike IGBC, GRIHA mandates certain minimum sustainability benchmarks, particularly for public and institutional projects. Over the past two decades, both systems have evolved to address emerging sustainability challenges such as net-zero energy targets, retrofitting of existing buildings, and resource-efficient urban development. Together, they have significantly influenced India's sustainable construction landscape.

2.1 Indian Green Building Council (IGBC)



(a) (b) (c)

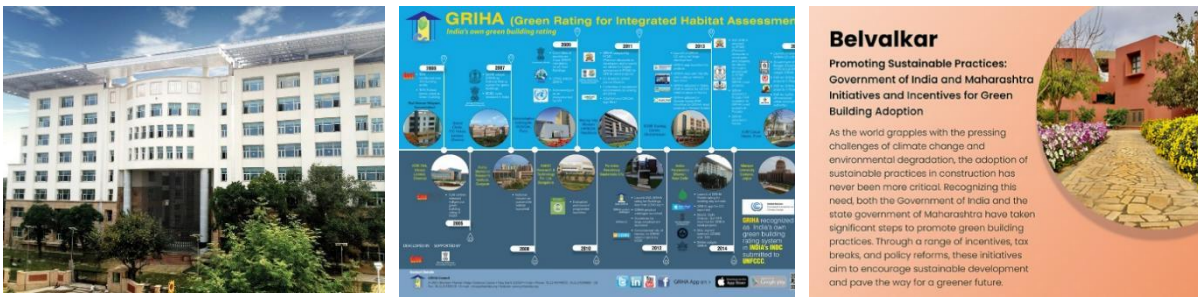
Figure a- Astral Pipes Manufacturing Facility
Figure b- CII Sohrabji Godrej Green Business Centre
Figure c- Suzlon One Earth

Established in 2001 under the Confederation of Indian Industry (CII), IGBC:

- Is voluntary and market-driven
- Adapted from LEED framework
- Offers multiple rating variants (Homes, Factories, Schools, Net Zero, etc.)
- Uses a point-based credit accumulation system
- Encourages innovation credits

IGBC significantly accelerated green certification in private commercial and residential sectors.

2.2 Green Rating for Integrated Habitat Assessment (GRIHA)



(a) (b) (c)

Figure a - Indira Paryavaran Bhawan
Figure b - Key Features
Figure c - Belvalkar Sustainable practive

Developed by TERI and adopted by MNRE as India's national rating system, GRIHA:

- Is performance-based
- Mandates minimum compliance benchmarks
- Integrates climate-responsive architecture
- Requires post-occupancy monitoring

- Aligns closely with national environmental policies

The well-known Indira Paryavaran Bhawan demonstrates GRIHA's climate-responsive and net-zero philosophy.

3.Objectives of the Study

The objectives of this research are to:
Conduct an in-depth comparative analysis of IGBC and GRIHA rating systems.
Examine overlaps, distinctions, and implementation challenges.
Analyze real-world application through detailed case studies of certified buildings.
Evaluate suitability across India's diverse climatic and socio-economic contexts.
Propose an integrated and performance-oriented framework for future green building development.

4. Research Methodology

4.1 Research Design

The study adopts a qualitative, comparative, and analytical research design. It combines secondary data analysis with descriptive case study evaluation to bridge the gap between theoretical frameworks and practical implementation.

4.2 Data Collection

Data was collected from the following sources:

- Official IGBC and GRIHA rating manuals and technical guidelines.
- Peer-reviewed journals, books, and conference papers on sustainable architecture.
- Government reports from MNRE, BEE, MoHUA, and MoEFCC.
- Published performance reports and design documentation of certified buildings.

4.3 Case Study Selection

Two institutional buildings were selected based on the following criteria:

- Certification under IGBC and GRIHA respectively.
- Similar functional typology (institutional/office use).
- Location in comparable climatic zones.
- Availability of documented sustainability strategies.

5 Case Studies

5.1 Case Study 1: IGBC-Certified Private Institutional Campus Overview:

The selected IGBC-certified project is a large private institutional campus located in a composite climatic zone. The project achieved IGBC Gold certification.

Sustainability Strategies:

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- High-performance building envelope with energy-efficient glazing.
- Extensive use of rooftop solar photovoltaic panels.
- Energy-efficient HVAC systems with building automation controls.
- Rainwater harvesting and on-site wastewater treatment.

Performance Insights: The project demonstrates strong compliance with IGBC prerequisites and innovation credits. Energy modelling indicates significant reduction in operational energy demand compared to conventional buildings. However, post-occupancy performance monitoring is limited to annual audits.

5.2 *Case Study 2: GRIHA-Certified Government Building*

The selected GRIHA-certified building is a government institutional building designed as a climate-responsive facility and awarded a 4-Star GRIHA rating.

Sustainability Strategies:

- Orientation and massing optimized for daylight and reduced heat gain.
- Passive cooling techniques such as shading devices and natural ventilation.
- Comprehensive water balance approach including zero-discharge planning.
- Construction waste segregation and lifecycle material assessment.
- Mandatory post-occupancy evaluation and performance documentation.

Performance Insights: The building exhibits lower operational energy consumption due to passive design strategies. Continuous monitoring ensures alignment between design intent and actual performance, though the certification process is time intensive.

6. Table 1. – Comparative Analysis

Parameter	IGBC	GRIHA
Approach	Energy modelling + renewables	Passive-first + lifecycle performance
Strength	Renewable integration	Reduced base load demand
Monitoring	Limited	Mandatory

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6.1 Energy Efficiency

IGBC emphasizes energy modelling, ECBC compliance, and renewable integration, while GRIHA prioritizes passive design and lifecycle energy performance. The case studies reveal that IGBC projects often achieve higher renewable capacity, whereas GRIHA projects demonstrate lower base energy demand.

6.2 Water Management

- IGBC adopts efficiency-driven strategies, whereas GRIHA implements holistic water balance
- models. GRIHA's mandatory approach ensures long-term water security.
- IGBC: Fixture efficiency, Rainwater harvesting.
- GRIHA: Comprehensive water balance, Zero-discharge strategy, Long-term aquifer sustainability. GRIHA demonstrates stronger ecological water plan.

6.3 Materials and Waste Management

- IGBC encourages innovation and regional sourcing, while GRIHA mandates embodied energy accounting and waste auditing, resulting in measurable environmental benefits.
- IGBC: Regional materials, Innovation credits
- GRIHA: Embodied energy calculations, Lifecycle material assessment, Waste auditing
- GRIHA offers measurable environmental accountability.

6.4 Indoor Environmental Quality

- Both systems address occupant comfort; however, GRIHA strengthens IEQ through post- occupancy evaluation, ensuring sustained human-centric performance.
- Both systems address: Thermal comfort, Daylighting, Indoor air quality
- However, GRIHA mandates post-occupancy IEQ evaluation, ensuring sustained occupant comfort.

6.5 Site and Socio-Economic Considerations

- GRIHA integrates ecological conservation and labor welfare more explicitly, reflecting India's
- socio-cultural context.
- GRIHA includes Ecological preservation, Labor welfare standards, Socio-cultural context integration.
- IGBC gives flexibility but fewer mandatory social criteria

7. Discussion

Comparative and case-based analysis highlight that IGBC and GRIHA serve complementary roles rather than competing ones. IGBC drives market transformation and private-sector

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participation, while GRIHA ensures regulatory alignment and environmental accountability. The absence of a unified benchmark and limited post-occupancy monitoring remain key challenges.

- IGBC drives market transformation
- GRIHA ensures regulatory alignment
- Both lack unified national benchmarking
- Post-occupancy performance gap exists

8. Policy-Level Recommendations

8.1 National Integration

- Develop a unified national sustainability baseline with mutual credit recognition.
- Mandate post-occupancy performance disclosure for certified buildings.
- Introduce simplified certification pathways for affordable housing.

8.2 For Designers and Developers

- Integrate sustainability goals at the conceptual design stage.
- Prioritize climate-responsive strategies over point accumulation.
- Educate occupants to ensure long-term building performance.

8.3 For Academic and Research Institutions

- Conduct longitudinal post-occupancy studies.
- Develop region-specific sustainability benchmarks.

9. Proposed Integrated Framework

This convergence would improve: Carbon accountability, Climate resilience, National sustainability alignment

IGBC Strength	GRIHA Strength
Market adaptability	Scientific rigor
Innovation incentives	Performance validation
Private sector appeal	Policy integration

10. Conclusion

IGBC and GRIHA have significantly advanced sustainable construction practices in India. However, future progress requires convergence rather than parallel operation. A harmonized, performance-based national framework that integrates IGBC's flexibility with GRIHA's scientific rigor can enhance accountability, improve real-world performance, and support India's transition toward a resilient, low-carbon, and inclusive built environment.

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Optimization of Human Thermal Comfort in Office Buildings: Case of Pune

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Abstract: Office buildings play an important role in the rapid urbanization and development of Pune city. Thermal comfort conditions in the office should be satisfactory for the user group. Human thermal comfort plays an important role in occupant well-being and productivity in office buildings. This paper explores key influencing factors, evaluates existing thermal comfort standards, and examines potential strategies for optimizing indoor environments. Climate change has led to increased thermal comfort and reduced energy consumption in office buildings. Optimal utilisation of climate-responsive strategies can play a decisive role in the enhancement of thermal conditions in office spaces. The aim is to examine the role of architectural interventions in enhancing human thermal comfort in office buildings. It looks at architectural elements enhancing human thermal comfort, climate-responsive materials used, quality of light and light control techniques, spatial distribution patterns, and ventilation patterns. The case study method is adopted, wherein three different medium-scale offices have been analysed and simulated to assess the thermal comfort of the users. A set of questions was administered to occupants in the office and analysed to identify emerging perceptions of comfort and adaptation. It enables simultaneous performance assessments of all building issues, including facade and wall construction, window glazing, HVAC systems, controls, indoor air quality, human thermal comfort, and energy consumption. The findings aim to contribute to the development of more efficient building design and climate-responsive thermal management solutions, ensuring both occupant satisfaction and sustainable energy use.

Keywords: Human thermal comfort; climate change; sustainable design; occupant well-being; architectural interventions

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1. Introduction

Office buildings face multiple challenges due to the accelerating impacts of climate change. Rising global temperatures and fluctuating humidity levels directly affect the indoor environment, making it more difficult to maintain acceptable comfort conditions. Climate change can significantly impact on the total energy consumption and indoor environment of buildings. Thermal comfort is based on dry bulb temperature, clothing level, metabolic rate, air velocity, humidity, and mean radiant temperature. Optimal utilisation of bioclimatic design strategies based on local climate can play a decisive role in the enhancement of indoor air quality (Daemei, 2019). Pune has a hot and humid climate. This type of climate requires ventilation, proper dehumidification, and cooling. Achieving optimal thermal comfort becomes particularly challenging due to high temperatures, excessive humidity, and varying occupant preferences. It is based on the use of materials within the construction that will help minimise consumption. Passive strategies to reduce heat gain include external wall insulation, roof

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insulation, windows, shading devices, and facade treatment (Kim, 2020). There is a need to introduce sustainable architectural interventions in office buildings.

2. Literature Review

2.1. Climate Change:

Climate change demands updated classifications to guide building design and adaptation. Traditional design is climate-responsive, using local materials to ensure comfort without active systems. Key parameters include temperature, moisture, precipitation, wind, and solar radiation. (Saifudeen, 2023).

Burning fossil fuels drives global warming and climate change, leading to rising temperatures, altered rainfall, more frequent extreme events (droughts, storms, floods, heat waves), sea-level rise, and impacts on human and ecological systems (Chipade, 2024).

Temperature is a key indicator of climate change, while the greenhouse effect—driven by rising greenhouse gases since the Industrial Revolution—causes global warming (Kharbade, 2017). Unplanned urbanisation intensifies climate change impacts (Parishwad, 2017). Climatic factors affect both the environment and human life, with rising temperatures indicating significant natural and human-driven changes (Jadhav, 2018).

Offices face high energy use and thermal discomfort due to climate change, requiring efficient, climate-responsive design and retrofits (e.g., EnerPHit), with performance influenced by location, orientation, and climate, while overheating is driven by poor shading, internal heat gains, and assessed using tools like dynamic thermal modelling and the OBTD index (Duran, 2021).

Cooling loads increase with climate, while overheating varies by floor level and orientation, and depends on building properties such as facade design, window performance (U- and g-values), shading, infiltration, and internal heat gains (Roetzel, 2012).

2.2. Key Parameters Influencing Thermal Comfort at Site, Building, and Occupant Levels

2.2.1. At the Site level:

Thermal conditions of a site depend on its location, climate zone, topography, surrounding microclimate, building density, adjacency, and natural vegetation.

2.2.2. At the Building level:

Building-level thermal conditions are influenced by orientation, spatial zoning, fenestration, thermal mass, materials, design strategies, and lighting and ventilation systems.

2.2.3. At the Occupant level:

The factors such as metabolic rate, clothing insulation, thermal preference, location of workspace, surfaces adjacent to the occupant, such as floor, ceiling, table, chair, and windows, affect human thermal comfort.

2.3. Factors affecting human thermal comfort and Occupant well-being

Comfort affects well-being and energy use. IEQ includes thermal, visual, acoustic, and air quality factors, managed by HVAC systems. Poor conditions can cause Sick Building Syndrome (SBS), influenced by both environment and occupant psychology.

2.3.1. Environmental Comfort Factors:

Air temperature, Radiation temperature, Air Velocity, Climatic conditions, acoustic and relative humidity.

2.3.2. Personal Comfort Factors:

Air temperature, Radiation temperature (Ghogare, 2021).

Architectural design can control physical variables, but not occupant-specific factors (Rowe, 2001). Human energy use depends on environmental conditions and body heat exchange, with thermal comfort models ranging from simple steady-state (Fanger) to advanced multi-node and transient models (Prek, 2006).

2.4. Architectural interventions in office buildings

Microclimate organisation involves control and regulation, while climate classification guides building design. Indoor comfort is maintained through ventilation and automated systems, with conditions shaped by external climate, indoor activities, and HVAC performance (Cheberiachko, 2022).

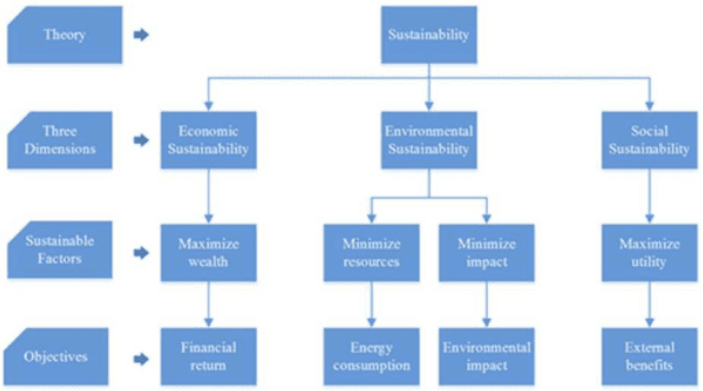
Multiple tenants create varying occupancy and microclimates in offices, which adaptive systems like DCV help manage, though peak occupancy and internal heat gains from events or equipment can still affect conditions (Abuimara, 2020).

Smart buildings enhance safety, comfort, and resource efficiency through automation, but comfort is often limited by poor insulation, inadequate thermal control, unsuitable temperatures, and vertical temperature variations (Niza, 2022).

2.5.Energy efficiency in office buildings

High internal heat from office equipment increases energy loads, making building energy-efficiency technologies (BEETs) essential for savings, though systematic research at the city scale remains limited (Wan, 2022).

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Source: (Wan, 2022)

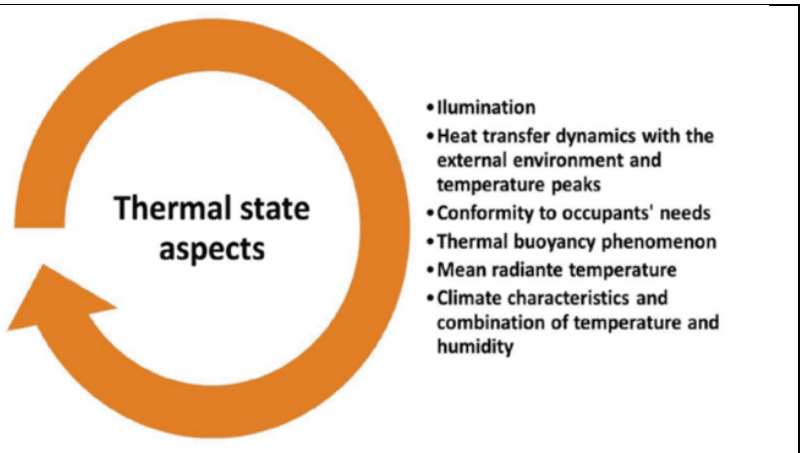
Figure 1. Framework of sustainable development of building retrofit

Effective temperature combines radiant and dry bulb temperatures, while humans maintain thermal balance as homeothermic beings; the PMV/PPD model is based on controlled steady-state comfort studies (Hens, 2008).

BMS-controlled HVAC systems often overlook individual comfort, while proportional control maintains zone temperatures within set ranges (Jazizadeh, 2014).

WWR: The window-to-wall ratio means the percentage of area covered by walls. The north direction should have more WWR, and the south direction must have WWR.

Building envelope design includes insulation, reflective coatings, efficient HVAC and lighting, and retrofit analysis for energy savings. ASHRAE defines standards for indoor thermal environments acceptable to most occupants (Albatayneh, 2021).



Source: (Albatayneh, 2021)

Figure 2. Aspects of the thermal state.

2.6. Passive strategies that can be incorporated into office buildings:

To increase light intake: Light well, Light shelves, atrium, courtyard, clerestory, northlight, skylights.

Shading devices: Fins, louvres, chajja, box windows, double skin façade.

To increase ventilation: Jali walls, Perforated panels, hybrid ventilation systems, VRV (Variable Refrigerant flow) air-conditioning system (Niza, 2022).

3. Methodology

3.1. Case study analysis:

This study will consist of a mixed-methods research design combining quantitative environmental measurements with qualitative survey data to assess human thermal comfort in office spaces. The approach enabled both objective analysis of environmental conditions and subjective assessment of occupant satisfaction.

Simulation:

Building simulation evaluates building performance using BIM (Building Information Modelling) software. It enables simultaneous performance assessments of all building issues, including facade and wall construction, window glazing.

3.1.1. Context analysis:

This will consist of climate analysis, the context of the office building, and the site surroundings.

3.2. Data collection:

3.2.1. Quantitative data:

Spatial data, WWR (Wall-to-window ratio), and insulation

Sample:

- Two office buildings in Pune incorporating passive strategies.
- One office space where thermal discomfort is observed.

3.2.2. Qualitative data:

Survey of occupants in the office (Thermal sensation, thermal comfort satisfaction, perceived air quality, productivity, and well-being)

- Questionnaire: A set of questions will be asked and analysed thematically to identify emerging perceptions of comfort and adaptation.
- Interviews: Communicating with the architects about designing office buildings considering the climatic factors.

Sample:

Office employees: Managers, Support staff

- Surveying people about thermal comfort conditions
- The people belong to various departments, including head officers, employees, supporting staff, and workers.
- Age group: 18-45 years
- Sample size: 25 people from 4 offices (both male and female)
- 10 People from BNCA, and 5 people each from ENPRO, Landscape Design Group Studio, PMRDA, Pune.

4. Case study analysis

These offices are located in Pune, which has a hot and humid type of climate. The on-site analysis of offices indicated architectural interventions such as orientation, facade treatment, shading devices, ventilation patterns, materials, and spatial distribution. It identifies climate-responsive design strategies that balance thermal comfort and energy efficiency.

4.1. Office 01, Pimpri Chinchwad:

This office consists of ground plus seven floors with a basement. The office is oriented north-south, which minimizes heat gain, glare in the office building.

Spaces are zoned by orientation to optimise light, ventilation, and thermal comfort: workspaces on the north, cabins and meeting areas on the west, and services on the south. Facade strategies include shading devices on the south, recessed windows and fins on the west, curtain walls on the north, and a double-skin facade on the east. Despite workspace depths over 7 m, adequate daylight is achieved through an atrium and diffused eastern light.

The structure incorporated an earth tunnel system, which provides cooling to the internal spaces. It consists of an atrium which allows light to enter the building, and facilitates the stack effect,

the warm air rises and escapes through the openings at upper level. An earth air tunnel, also known as an earth air heat exchanger, is an essential technique that is used for the pre-cooling or pre-heating of a system that consists of a pipe, duct, or tunnel network buried underground at

a reasonable depth. There is less occupant control on operable windows and adjustable fins due to mechanical air-conditioning. Thermostats are adjustable in the common workspace zone.

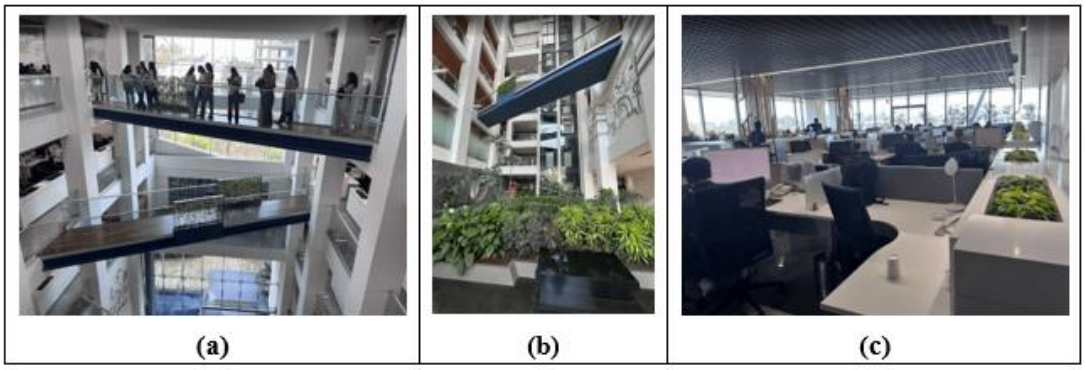


Figure 3. (a) East side incorporates natural light **(b)** Atrium **(c)** Open floor plan- Workspaces
Source: Author



Source: Author

Figure 4. Case Study of office 01

4.2. Office 02, Pune -

The office consists of four mezzanine floors, which allow light and ventilation to flow without any restriction. The building is oriented north-south. It consists of a hybrid ventilation system for air-conditioning and fans that uses a combination of natural airflow via windows and vents and mechanical ventilation fans to provide optimal indoor air quality and comfort while reducing energy consumption.

Adjustable fins on the north control daylight, while reduced, linear openings on the east and west minimise heat gain (low WWR). The south facade is mostly blank with small louvred openings, housing services like stairs and storage. A central atrium enhances airflow and enables stack effect ventilation to workspaces.

The office uses natural materials such as wood for fins. Exposed concrete is used, which reduces the inside temperature.

Jali is used in the internal spaces to cool down the air passing through it due to the venturi effect. Stone cladding is used in internal spaces.

Water features are used to reduce surface temperatures. The ground floor is designed to ensure cool air passes through the spaces located on the ground floor.

The cooling/ heating loads reduce due to the passive strategies used in the building. There is an increase in energy efficiency due to a reduction in energy consumption

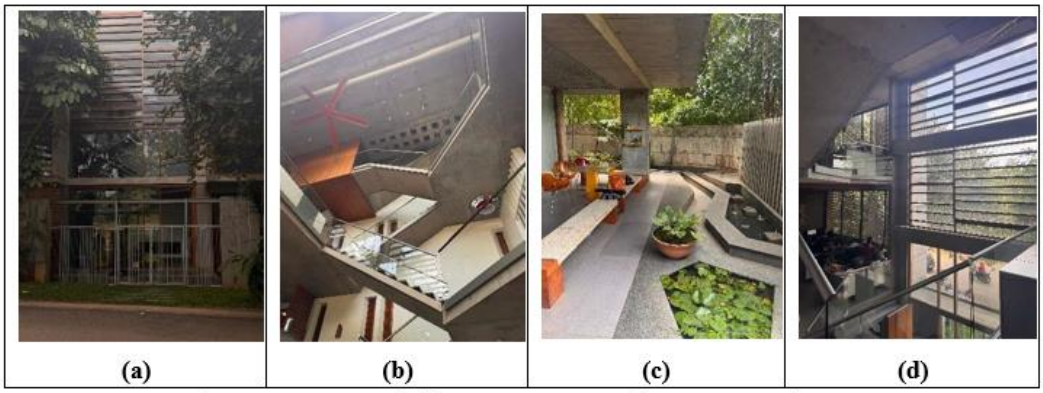


Figure 5. (a) Façade treatment **(b)** Hybrid system **(c)** Water features **(d)** Atrium
Source: Author

4.3. Office 03, Pune:

This research is based on learning strategies from the case study, and analyzing the office space in Institutional college, present on the ground floor. The office is located on the north side and is adjacent to corridor spaces near the courtyard.

Natural daylighting is insufficient as the depth of the office is more than 7m. The WWR ratio is very low to allow sufficient daylight penetration. Diffused light enters the office due to its orientation. There is a need for the use of artificial lighting in the daytime.

Due to the spatial distribution of the office spaces, the air movement is restricted. The partitions and cubicles do not allow air to flow from one space to another. The partitions are made of glass and plywood. Ventilation is provided using a combination of Split Air-conditioning systems and ceiling fans.



Figure 6. Images showing office space and adjacent surroundings
Source: Author

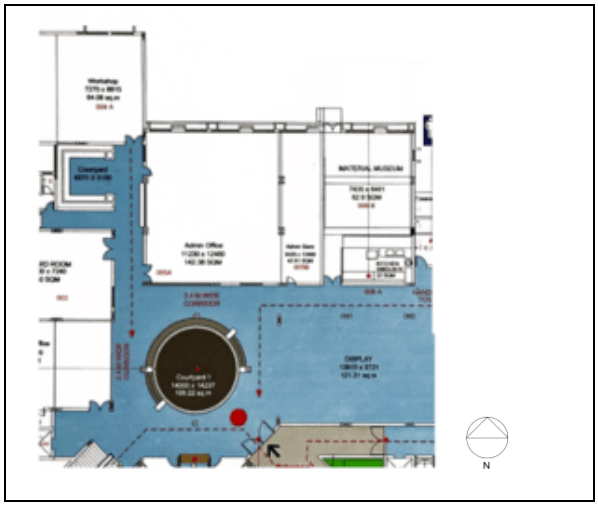


Figure 7. Plan of office
Source: Author

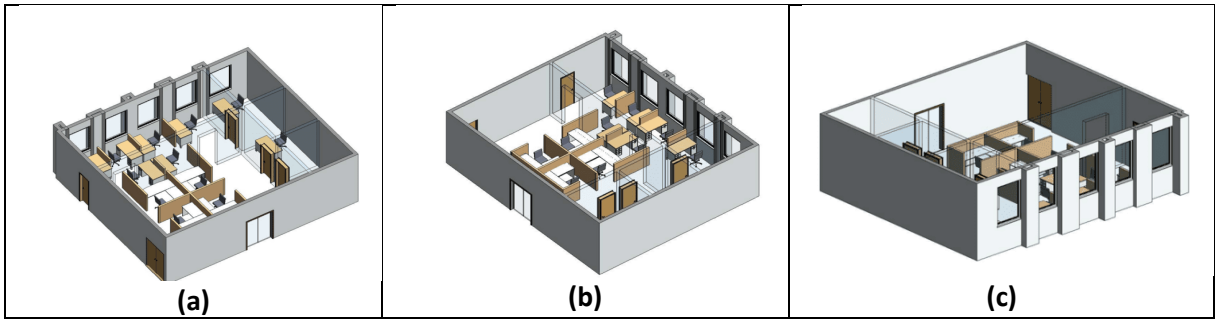


Figure 8. Model for office space
Source: Author

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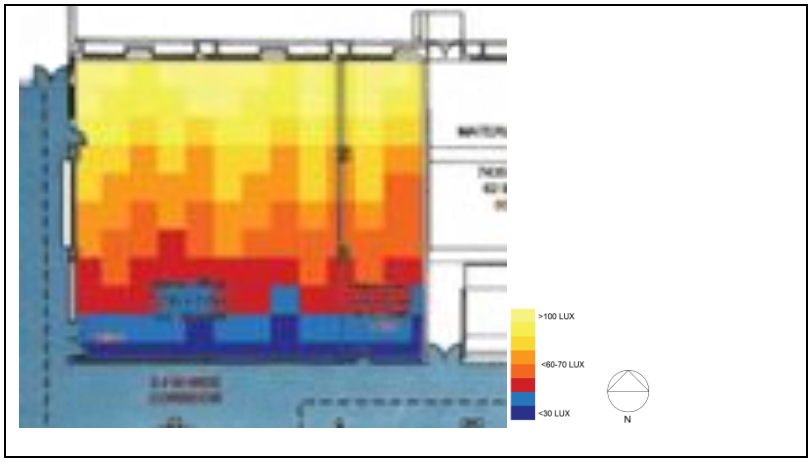


Figure 9. Lux levels in the office space. The light is insufficient for working areas.
Source: Author

5. Interviews:

5.1. Interviewee 1:

Sustainability in office buildings focuses on integrating energy-efficient systems for light and ventilation control. Building orientation and the design of the building envelope are essential considerations in minimising heat gain and maximizing daylight. The office layout should be flexible, allowing for reconfiguration of spaces based on functional needs. Adaptability in design enhances user comfort and long-term usability of the building. Critical work hours must be carefully addressed to optimise thermal comfort in the office. The combination of passive strategies and active systems can contribute to reduced energy consumption.

5.2. Interviewee 2:

Properly designed shading devices can help reduce the overall energy load by 8–10%. Since the roof and external walls are the primary sources of heat gain, strategies to minimise heat transfer through these components are essential. Maximum heat is gained by roofs and walls. By creating a cavity in the wall, temperature can be reduced inside the structure. The sun is in direct contact with the building envelope. If the temperature is reduced at the transmission level, the indoor temperature reduction will decrease. Using filler slabs can increase the thermal mass of the structure. Applying terracotta chips as insulation on the terrace creates air gaps that limit heat gain, and applying reflective surfaces on terraces, such as China mosaic, helps to reflect solar radiation. Hollow core slabs can be used as they have air gaps inside them. Through appropriate roof treatment, internal temperatures can be reduced by 4–7°C. Green roofs are designed based on the heat load. More than 50% of energy costs are used for operational costs such as air-conditioning systems. VRV systems can be used for an 18% reduction of operational costs. A combination of Evaporative cooling and HVLS (High Volume Low Sound) fans can be used. Solar energy can be utilised.

Sustainable architectural design should integrate the five elements of nature cohesively:

- **Fire -** Sun: Harnessing solar energy
- **Air –** To promote Cross-ventilation, Air-conditioning
- **Water** – To incorporate RWH, recycling water, and STP
- **Earth** – Using Natural elements for insulation, base
- **Space** – Enhancing Spatial quality, light, ventilation, and personal factors

6. Research and findings

This research adds to the knowledge of empirical data collected through office employees from office 03, and other offices where passive strategies have been applied.

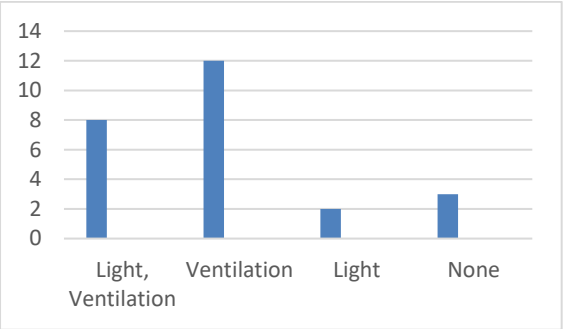


Figure 10. Reasons for which the office space is uncomfortable

The maximum number of people feel uncomfortable due to the ventilation. This issue occurs in open workspaces due to a lack of personalisation and varied preferences in comfort conditions in office spaces.

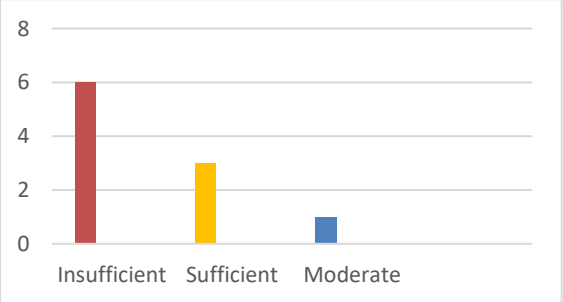


Figure 11. Lighting Conditions

It is observed that the people working near walls, corridors and the centre of the office do not get sufficient light. Incorporating light with passive techniques such as light shelves, light wells and clerestories can penetrate light inside the structure.

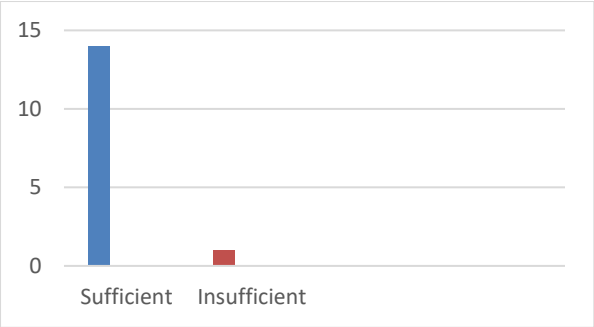
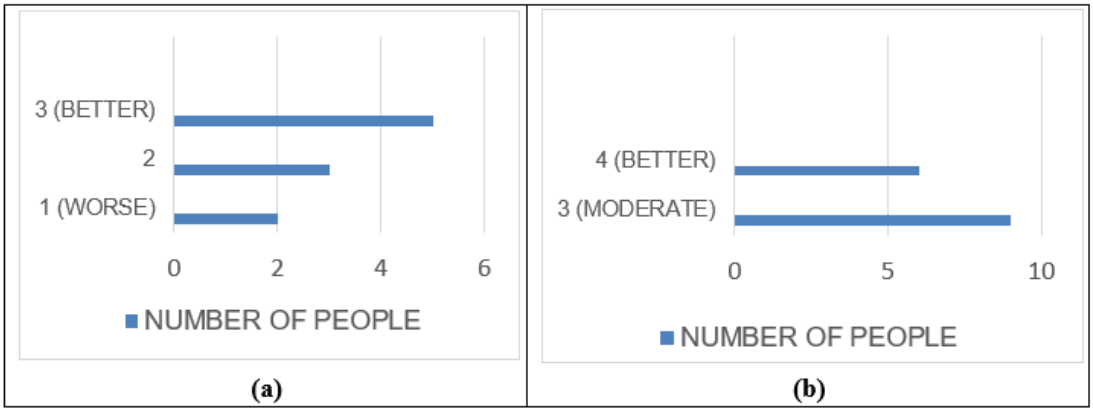


Figure 12. Lighting conditions

The light is sufficient due to the orientation of the building, WWR, depth of the building.

Figure 13. (a) office 03, Admin office **(b)** office 01, office 02



Ventilation Conditions

In the Admin office, ventilation is inadequate because the interior layout includes several enclosed areas and barriers that restrict airflow, whereas other office spaces allow ventilation due to open floor plans, using hybrid ventilation systems.

The spatial configuration of the office building should be according to the climatic conditions and the microclimate of the surroundings.

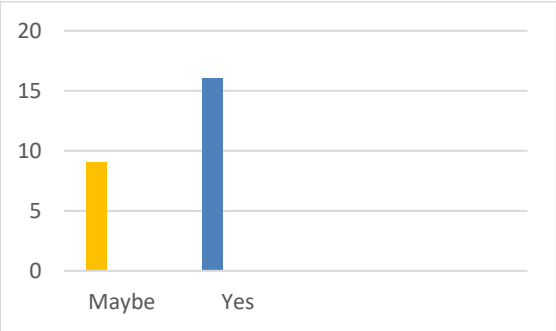


Figure 14. Ventilation systems

Most of the people prefer natural ventilation systems, it enhances the indoor air quality and increase productivity of employees.

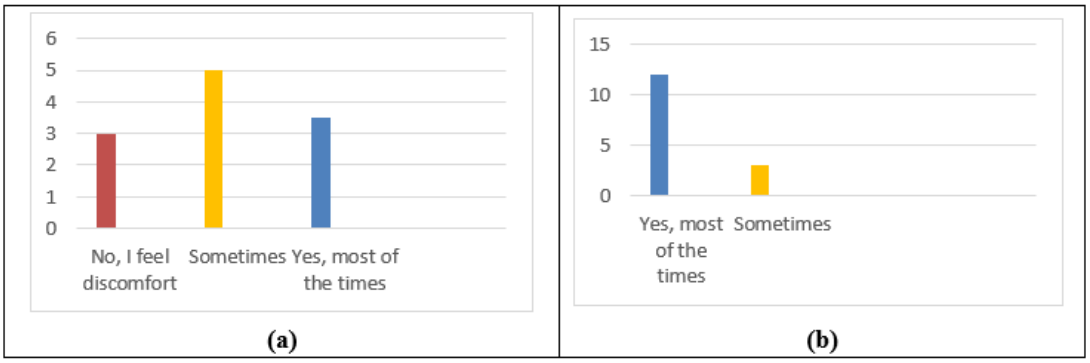


Figure 15. (a) Indoor temperature in office 03, Admin (**b)** Indoor temperature in office 01 and 02

The high occupancy in the office makes it hard to adjust the temperature to everyone's comfort level. Flexibility and user control over indoor conditions, such as daylight and ventilation, are essential to address the diverse perceptions of comfort.

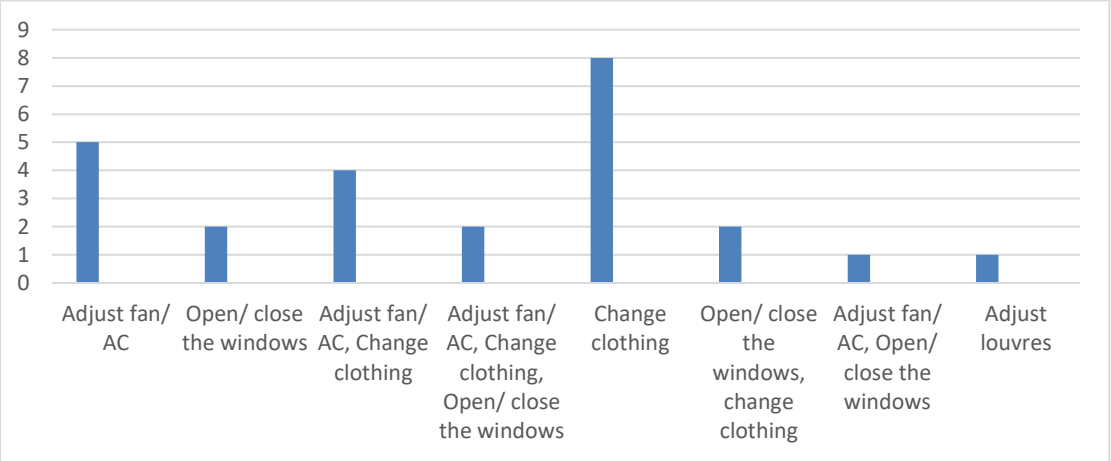


Figure 16. Actions taken by people when they feel discomfort

The people prefer to adjust the fan/AC, change clothing due to the central air-conditioning systems, leaving little opportunity for natural ventilation, since the windows are rarely operable. The cabins can be modified according to their needs due to control over air-conditioning systems.

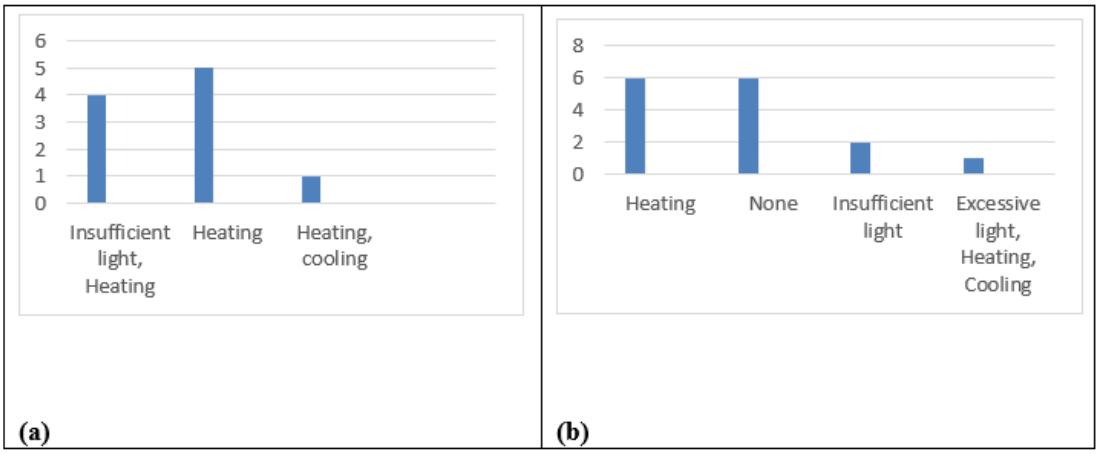


Figure 17. (a) office 03, Admin **(b)** office 01, Office 02

Reasons for Discomfort

Excessive heat is the main reason for thermal discomfort in the office. The spaces lack effective cooling strategies, which makes it difficult to maintain a pleasant indoor environment, especially during warmer months. Without proper cooling measures, the rooms tend to trap heat, leading to an uncomfortable working atmosphere for the occupants.

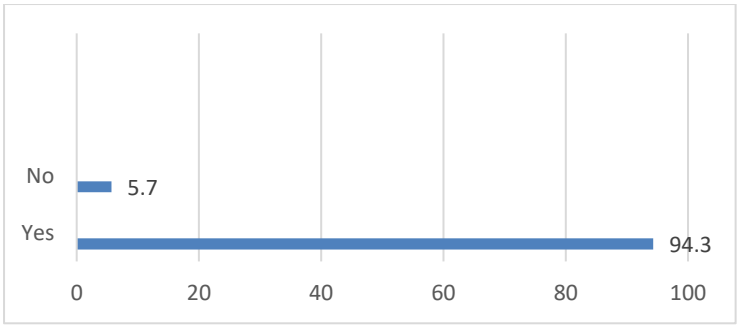


Figure 18. Effect of Spatial Distribution, color and form

The materials, colours, form, and overall layout of a workspace have a significant impact on employees' comfort and productivity. Elements such as the orientation of desks and chairs, the arrangement of furniture, workspaces, and the reflectivity of surface colours all influence how people experience and interact within the space. Well-designed spaces can affect the efficiency of employees.

7.Discussion:

The office 03, Admin can be modified with an open-plan arrangement with perforated surfaces used for partition, not to restrict airflow. The light should be incorporated in the office spaces by increasing the WWR, using light fixtures that provide sufficient illumination without generating excess heat. The cubicles can have personalized ventilation systems that can run through the partition and can be easily personalized. Features like clerestory windows could be

added to the existing walls to bring in and reflect more natural light throughout the space. The windows can be glazed, and they could mould according to the light required inside the space. Enhancing its operation and integrating it with these design improvements could significantly improve indoor comfort and overall workplace quality. Although a hybrid ventilation system is already in place, it is not being utilised to its full potential. Enhancing its operation and integrating it with these design improvements could significantly improve indoor comfort and overall workplace quality.

8.Conclusions -

Users:

The users comprise mainly of 22 to 45-year age group. The people feel discomfort due to the micro-climatic conditions of the office spaces. The office spaces could consist of systems that could be designed according to employees' needs.

Buildings:

The buildings should be designed according to the physical factors affecting the spaces. The space defines the micro-climatic conditions inside the building, which affects the productivity of office employees.

The analysis will help to provide valuable insights for designing office buildings that priorities thermal comfort, ultimately enhancing the efficiency and productivity of workplace environments. This research can serve as a practical reference for materials and passive strategies for architects and designers for planning new office spaces. As many offices increasingly face challenges brought on by climate change, it becomes essential to design buildings that respond not only to general climatic conditions but also to the specific micro-climatic conditions.

AI Usage Disclosure

The authors acknowledge the usage of Artificial Intelligence (AI) during the preparation of the paper. ChatGPT (GPT-5) and Grammarly were used only for grammar correction, language refinement and clarity.

The conceptual framework, methodology, data analysis, conclusions, and final interpretations were carried out by the authors, without any involvement of AI systems.

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Towards Ecological Resilience: Sustainable Planning Strategies for Jotiba Temple Precinct, Kolhapur.

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Abstract: Amongst the various pilgrimage sites in India, the Jotiba Temple at Wadi-Ratnagiri, Kolhapur, stands as an important religious and cultural landmark with significant regional influence. Despite its prominence and the daily arrival of 5,000–10,000 pilgrims—escalating to more than 5–8 lakhs during the annual Chaitra Yatra—the existing infrastructure remains insufficient to accommodate such large numbers. The temple precinct faces challenges of limited carrying capacity, haphazard development, traffic congestion, inadequate sanitation and waste management, and increasing environmental pressures on the surrounding hill ecosystem. These shortcomings not only compromise the overall pilgrimage experience but also endanger the cultural and ecological sustainability of the site. The research has been carried out through numerous site visits, documentation and research through historical books which were limited in number and hence most of the data was through interview forms.

This paper examines the infrastructural gaps within the temple complex and proposes the adoption of sustainable construction practices and ecological site planning as a response. Interventions such as context-sensitive circulation systems, renewable energy integration, water-sensitive design, centralized waste management, and ecological landscape buffers are highlighted as effective strategies. By aligning pilgrimage infrastructure with principles of sustainability, the study aims to enhance visitor experience, preserve cultural heritage, strengthen local livelihoods, and ensure long-term ecological resilience of the temple environment.

Keywords: Jotiba Temple; Pilgrimage infrastructure; Sustainable construction and environmental resilience.

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1. Introduction

Background

Kolhapur in Maharashtra is located between 15°–17° N latitudes and 73°–74° E longitudes and covers an area of 7,692 sq. km; with a population exceeding five lakhs (Census, 2011). Referred to as ***Dakshin Kashi***, the city is renowned for its rich religious and cultural heritage, exemplified by landmarks such as the Mahalaxmi Temple, Bhavani Mandap, and the Jotiba Temple complex.

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The Jotiba Temple, situated near Wadi-Ratnagiri approximately 19 km north of Kolhapur at an elevation of 3,124 feet above sea level, is a significant hill shrine dedicated to Lord Jotiba—an incarnation of Lord Shiva. Constructed in the traditional Hemadpanthi architectural style, the temple complex comprises the Kedareshwar, Jotiba, and Ramling shrines, along with the Yamai Temple, dedicated to Goddess Yamai, located on the same hill. The pilgrim center attracts an estimated 5–8 lakh pilgrims annually from Maharashtra and neighbouring states such as Karnataka, Goa, Andhra Pradesh, and Tamil Nadu, with peak gatherings during major festivals like Chaitra Yatra, Shravan Shashti, Khete and Navratri. These celebrations, characterized by elaborate rituals, processions, and community participation, contribute to the intangible cultural heritage of the region.





Figure 1: Aeriel view of Jotiba temple and **Figure 2:** Jotiba temple
Source: Ar. Seza Samadhan.

Table 1.1 given below depicts the year wise pilgrims visiting Jotiba temple:

Year	Annual yatra- Chaitra month
2016	7 lakhs devotees
2022	5-6 lakh devotees
2023	8-10 lakh devotees
2024	5 lakh devotees
2025	Over 10 lakh devotees

Table 01: Pilgrim visits during Chaitra month
Source: Times of India.

Table 1.2 given below shows the number of pilgrims visiting the important dates of religious concerns in the year 2022. The figures show that there has been a consistent growth in the

Sr. No.	Event/ Festival Details	English Months	Footfall/ Day	No. of Days	Total no of Footfall
1.	5 Khete on Sundays	Feb/ March	1,25,000	5	6,25,000
2.	3 days before Chaitra Yatra	March/ April	2,00,000	3	6,00,000
3.	Chaitra Yatra)	March/ April	4,00,000	3	12,00,000
4.	3 days after Chaitra Yatra	March/ April	2,00,000	3	6,00,000
5.	Chaitra Month	March/ April	30,000	21	6,30,000
6.	Pakalani Yatra	March/ April	2,00,000	1	2,00,000
7.	Summer Vacation	May/ June	60,000	15	9,00,000
8.	Shravan Shashti Yatra	July/ August	4,00,000	1	4,00,000
9.	Nagar pradakshina	August	4,00,000	1	4,00,000
10.	Navratri & Dusshera	Sept-Oct	1,00,000	10	10,00,000
11.	Diwali	October	60,000	10	6,00,000
12.	Tripurari Pournima	November	2,50,000	1	2,50,000
13.	Pournima	Whole Year	1,00,000	10	10,00,000
14.	11 Maruti Dindi		15,000	1	15,000
15.	Christmas	December	60,000	10	6,00,000
16.	लग्न सराई	Nov-Dec	30,000	30	9,00,000
17.	Every Sunday	Whole Year	50,000	32	16,00,000
18.	Weekdays (Monday to Saturday)	Whole Year	8000	208	16,64,000
Total no. of Devotees (Year 2022)			**1,31,84,000 per year** (Considering 10% less in Total Footfall)		

number of pilgrims visiting Jotiba every year except the period of Covid 2022 where there is a dip in the number of pilgrims.

Table 02: Important dates of religious concerns
Source: Times of India.

2 Religious tourism

Religiously motivated travel, such as pilgrimage, is one of the oldest forms of tourism.(Choe, 2025) Over the past fifty years, as globalization and technological advancements have facilitated travel and communication, religious tourism has expanded globally in various forms because of the growing interest of the people in spirituality and cultural exchange. After pandemic, the search for meaning and purpose of life has further

renewed interest in religious and spiritual travel. Due to the increasing trend of religious tourism, it has been viewed as a strategy to improve the economy of the region. This economic development not only influences poverty alleviation, sustainability, accessibility, but also impacts the environment. However, its rapid expansion also exerts considerable pressure on local environments. Many destinations have begun to exploit religious tourism as a tool for national branding or as a means of generating revenue, which, if over-commercialized, can disrupt the authenticity of visitor experiences and discourage repeat visitation. While religious tourism can promote economic growth, diversify tourism offerings, and contribute to poverty reduction, its long-term sustainability depends on visitor behaviour, effective site management, and the extent of its impacts on host communities. In certain places, religious tourism also faces challenges in sustainable management, lack of funding, inadequate power distribution, insufficient business skills, low awareness, poor infrastructure, conflicts among various stakeholders and concerns about the commercialization of religious heritage, as well as corruption. The promotion of religious tourism prioritizes fund accumulation and development resulting in substantial investments in the religious sites and their environs at the expense of neglecting the rest of town and community.

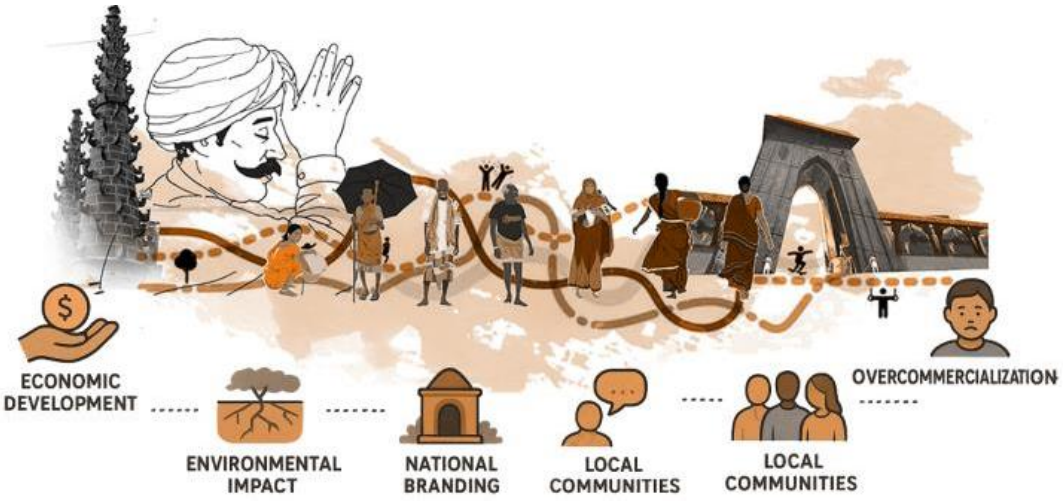


Figure 03: Religious tourism w.r.t Jotiba temple
Source: Ar. Seza Samadhan.

3 Comparative analysis of Vaishno Devi shrine and Sabarimala temple

The **Vaishno Devi temple at Katra along the** Himalayan foothills; is a highly institutionalized and very well-established shrine visited year-round. It contributes largely to the Jammu Kashmir's tourist arrivals and towards the local economy(Singh Suresh & Bahadur Raj, 2018). On the other hand, Sabarimala is located deep inside the Western Ghats and has seasonal tourists who visit the place in short windows.




Figure 04 and 05: Vaishno Devi temple, Katra and Sabarimala temple, Kerala.
Source: https://www.incredibleindia.gov.in/

Table 1.3 below brings out the comparative analysis between the two pilgrim centers with different contexts and the challenges faced by them.

Parameters	Vaishno Devi temple	Sabarimala temple
Location & setting	Along Himalayan foothills	Along the western Ghats; forest and riverine setting
Pilgrimage pattern and footfall	All throughout the year.	Seasonal tourists
Cultural Context	Broad-based Hindu pilgrimage; supports identity and tourism branding for J&K.	Deeply ritualistic; linked to forest culture and tribal traditions; subject to social debates (e.g., gender entry).
Type of Pilgrimage	Highly institutionalized religious pilgrimage.	Seasonal, nature-embedded, ritual trekking pilgrimage.
Governance and management presently	Managed by Shrine Board; well-documented tourism–economic link; data-driven monitoring.	Lack of integrated masterplan; recommendations emphasize land-use control, zoning, and master planning.
Footfall pattern	Steady but annual flow of pilgrims	Short duration but massive inflow.
Access & Transport	Base at Katra; organized pedestrian route available and services such as palanquins / dolis, helicopter & pony routes available.	Base at Nilakkal; road to Pamba; trekking to Sannidhanam; congestion due to private vehicles near floodplain.
Infrastructure facilities made available for pilgrims	Permanent facilities: hotels, kiosks, organized accommodation; continuous expansion.	Ad hoc, temporary and semi-permanent structures along floodplain; poor construction quality revealed post-flood.
Environmental stress	Chronic issues: waste, sewage, deforestation, pollution from transport.	Acute issues: flood vulnerability, sand deposition, floodplain encroachment, ecological degradation.
Disaster Risk	Moderate – On account of landslide, wate related pollution.	High - Floods and instability due to the flood plains.

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Challenges	Overcrowding, solid waste and sewage management, resource pressure.	Flood hazard, ecological damage, unregulated construction, seasonal strain on services.
Socio-Economic Impact	Major employment and income generator; contributes to regional GDP.	Seasonal employment; benefits uneven; tribal livelihoods (Malai Arayan) need inclusion.
Core planning needs	Sustainable tourism plan: waste management, eco-friendly facilities, renewable energy.	Flood-resilient masterplan: restrict floodplain building, shift infrastructure to Nilakkal, ecological restoration.
Recommended actions	Strengthen continuous management, adopt digital pilgrim monitoring, improve green transport.	Relocate functions to higher ground, use electric buses, re-naturalize river edge, integrate tribal participation.

Table 03: Comparative analysis between the 2 shrines
Source: Author.

4. Inferences from the case studies

In case of **Mata Vaishno Devi Shrine**; the paper recommends the need for environmental management, community participation, and policy enforcement to balance tourism growth with ecological preservation. The key recommendations are (Singh Suresh & Bahadur Raj, 2018)



Implementing **sound environmental planning** and **eco-friendly construction practices**, supported by strict regulations and monitoring mechanisms.



Imparting the importance of **environmental education and awareness** among visitors and local residents to foster responsible behaviour.



Implementation of effective waste and sewage management systems which shall include waste segregation, recycling, scientific treatment facilities, and the prohibition of polythene use.



Prioritising reforestation and protecting native vegetation, alongside careful monitoring of tourism-related development to prevent deforestation.



Address air pollution and climate change by adopting use of renewable energy and use of battery-operated or low-emission transport, and regular emission monitoring.

The paper thus concludes that religious tourism plays a pivotal role in achieving **sustainable regional development** if managed systematically. However, unchecked and unregulated growth can lead to ecological degradation, thus making **sustainability-oriented planning and community engagement** essential for long-term success.

Through the Sabarimala case study, the document outlines a durable and adaptable design strategy for the Pamba–Sannidhanam–Nilakkal pilgrimage route post the 2018 Kerala floods (V) (Kale Renuka & Yehuda Roshni Udyavar, 2017):



Developing Nilakkal as the main base camp for parking, retail, and pilgrim services, thereby **alleviating environmental stress on the delicate Pamba floodplain.**



Plying of electric and public transportation between Nilakkal and Pamba, and limit to use of private vehicles. Pamba to operate exclusively as a transit and ceremonial area, with some temporary amenities instead of permanent structures by the riverbanks. The policy measures include limiting private land ownership, decentralizing authority to Nilakkal, and promoting community stewardship.



The pilgrim facilities to emphasize use of **eco-sensitive, low-impact, and temporary structures** built using **local materials** such as bamboo and mud. The design promotes **crowd regulation**, **gender-inclusive access**, and **tribal participation**, integrating the knowledge and local craftsmanship

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Planning for sustainable pilgrimage in Sabarimala should incorporate environmental rehabilitation, community involvement, and resilience to disasters, turning the pilgrimage route into a paradigm of environmentally aware religious tourism.

5 Study of Jotiba and factors affecting the centre

Jotiba sees a large number of pilgrims amounting to lakhs during the major festivals during the various times of the year. The various factors affecting the stake holders which include the pilgrims and tourists; temple trust and the local communities, are as follows:

1. Environmental Factors

- **Excessive *Gulal* and Temple Waste:**

  Large quantities of *gulal,* coconuts, flowers, and food offerings are left behind after the yatra, contaminating soil and nearby water sources. *Gulal* is majorly offered during the yatra and settles down as a thick layer on temple steps and pathways thereby making it difficult for cleaning and increases water usage, sometimes leading to runoff contamination. Synthetic *gulal* often contains heavy metals (lead, chromium, mercury) and artificial dyes that leach into soil and nearby streams, affecting vegetation and aquatic life. Fine powder particles increase local air pollution levels during the festival, causing temporary smog-like conditions and leading to eye and skin irritation, asthma or allergies etc.



Figure 06: Gulal smeared in various places in temple area.
Source: Ar. Seza Samadhan

As per the interactions with the temple trust, devotees and local vendor,

- Suppose each devotee uses about ½ kg of *gulal*
- Assume a typical packet bought/used is 100g (0.1 kg) per devotee (so 5 packets per devotee if 0.5 kg each).
- In the years 2025 visitor number: -1000,000 devotees.

Calculation:

- Number of devotees = 1000,000
- If each uses 0.5 kg → total *gulal* = 1000,000 × 0.5 kg = **500,000 kg (i.e., 500 tonnes)**
- If per packet is 0.1 kg → number of packets = 500,000 kg ÷ 0.1 kg = 5,000,000 packets
- **So, average per person = about 5 packets (5,000,000 ÷ 1000,000)**

If we assume a more modest usage – say 0.25 kg each (2.5 packets) – then:

- Total *gulal* = 1000,000 × 0.25 = 250,000 kg
- Packets = 250000÷ 0.1 = 25000,000 packets
- **Average ≈ 2.5 packets/person.**

The use of *Gulal* during one festivity to the tune of 5,00,000 kg itself is alarming.

The other offerings which include flowers or coconut; decompose in the water and can deplete oxygen levels causing dead zones where aquatic life cannot survive. Furthermore, all these offerings are often given in plastic bags which are often discarded after use, covering the temple steps, forested slopes, and access roads. The plastic not only contaminate the temple surroundings, nearby streams, and groundwater but also affect the stray animals who may ingest the same when mixed with food waste or offerings, leading to choking or digestive blockages.

- **Soil Erosion and Deforestation:**

Continuous pilgrim movement via the hill slope where the locals usually come from and unplanned construction have disturbed natural contours and vegetation.



Figure 07: Evolution of the site from 2013 to 2025
Source: Ar. Seza Samadhan

- **Air and Noise Pollution:**

High vehicular inflow, loudspeakers used during the festivities and yatra, and diesel generators during yatras degrade the peaceful environment of the locals.

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- **Water Scarcity:**

- The hill lacks a natural water source, and existing supply systems are overburdened during peak yatra.

2. Socio-Cultural Factors

- **Commercialization of Faith:**

Uncontrolled stalls and temporary encroachments reduce the sanctity and traditional aesthetics of the temple.

- **Cultural Erosion:**

  The Gurav Samaj (temple priest community) traditions are being overshadowed by tourism and lack of livelihood opportunities.

- **Lack of Interpretation and Awareness:**

  Pilgrims are unaware of the temple's historical and spiritual significance.

3. Infrastructure & Management Factors

- **Congestion and Unplanned Parking:**

  Narrow approach roads and lack of parking facilities create traffic chaos during festivals.

- **Inadequate Amenities:**

  There are a few restrooms, resting spaces, and Bhojnalaya
  (community kitchens) for pilgrims.

- **Poor Waste Management System:**

  No segregation or recycling of temple waste (*gulal*, coconuts, flowers). No proper area where food waste can be collected and disposed of later.

- **Safety Concerns:**

  Overcrowding during yatra poses fire and stampede risks which have not been adhered to.

4. Architectural & Heritage Factors

- **Lack of Conservation Measures:**

  The old stone structures and steps face erosion, plastering, and random paintwork, which needs to be addressed maintaining the sanctity of the place.

- **Uncontrolled Additions:**

  New shops and tin-roofed shelters obstruct the visual integrity of the temple complex.

- **Loss of Visual Axis:**

  Encroachments disturb the sacred visual connection between the temple and surrounding landscape.



Figure 08: The present state of the temple structure; temporarily repaired with random plastering etc.
Source: Ar. Seza Samadhan

6. Sustainable Measures for Revitalization of Jotiba

Jotiba Temple, a significant cultural and religious site holds deep spiritual importance for millions of devotees. Known for its vibrant festivals and historical legacy, the temple attracts a large number of visitors annually. Despite its prominence, the temple complex faces several challenges, which after the study of various case studies can be addressed as under:

6.1 Infrastructure & Mobility Sustainability

- **Integrated Mobility Plan:**

  The current system sees more of state transportation and use of private vehicles which come in huge numbers and create chaos due to insufficient parking facilities. Introduction to shuttle services, pedestrian pathways, and encouragement to use of EV vehicles and provision of EV parking zones may help the pilgrim center.

- **Designated Parking and Entry Control:**

  There should be regulations or limits for vehicular access near the temple which needs to be adhered to and create peripheral parking lots.

- **Public Amenities Upgrade:**

  Facilities like affordable MTDC-standard restrooms, resting pavilions and shaded pathways need to be created with local stone and bamboo thereby promoting sustainability.

6.2. Environmental Sustainability

- **Temple Waste Recycling Center:**

Introduce the use of *eco-friendly herbal colors* made from turmeric, beetroot, or flower petals. Instead of gulal and provide the same in cotton pouches, paper cones, or biodegradable corn-starch bags for carrying.

  - If not the use of above; convert the *gulal* into natural dyes and craft products.

  - The other waste like flowers and coconut waste can be converted into organic manure. The dried flowers can also be used to make incense sticks.

- **Rainwater Harvesting & Greywater Reuse:**
  - Integrate tanks along slopes and reuse greywater for sanitation.

    a) Native Plantation & Green Buffer:
  - Along the approach roads reintroduction of local species (e.g., banyan, neem, peepal) to stabilize soil and filter runoff.

- **Eco-friendly Yatra Practices:**
  - Promote use of natural gulal, reusable cloth bags, and biodegradable offerings.
  - **Encourage environmental education and awareness** among visitors and local residents to foster responsible behaviour.

6.3. Cultural & Social Sustainability

- **Interpretation Center:**
  The cultural value of the center needs to be imparted to the present generation and thereby educate the youth and visitors on Jyotiba's mythology, rituals and Gurav Samaj heritage.

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- **Skill Development for Gurav Samaj:**
  Train the locals in eco-tourism, craft making, and waste recycling of *gulal*, flowers, coconut etc. and put it to use for income generation.

- **Cultural Festivals & Exhibitions:**
  Promote the cultural essence by highlighting the local art, music, and traditions to maintain living heritage.

6.4. Architectural & Heritage Conservation

- **Conservation of Temple Structures:**

  The conservation efforts should be initiated at Jotiba Temple complex and adopt heritage-sensitive conservation practices; to ensure structural integrity and authenticity. The traditional stone steps and architectural elements must be cleaned and repaired using lime-based mortars rather than modern cement, maintaining material compatibility and breathability. The surfaces should be treated using contextually appropriate, breathable finishes that respect the original texture and color palette. Furthermore, implementing periodic structural assessments, visitor flow management, and effective rainwater drainage systems will mitigate erosion risks and sustain the temple's historic character and spiritual sanctity.

- **Guidelines for New Additions:**

  Any new additions catering to the requirements of the local community, temple trust and pilgrims shall complement heritage architecture in form, color, scale and encourage use of locally available materials.

6.5. Administrative & Policy Measures

- **Temple Management Plan:**

  The temple trust should form a joint committee with the tourism department and the Kolhapur Municipal Corporation and make sure that they encourage pilgrims to participate and "celebrate faith sustainably" and also provide them a good pilgrim experience.

- **Crowd & Waste Monitoring:**

  The crowd management needs to be implemented with the use of smart sensors or CCTV so as to monitor waste collection and visitor flow.

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7 Conclusion

The Jotiba Temple, nestled in the mountainous terrain of Kolhapur, is not only a significant religious site but also a cultural and historical landmark that attracts lakhs of devotees annually. The main aim of this research is to analyse the existing tourist pattern and facilities available and then emphasize how religious tourism could help in achieving sustainable development of the region. The findings suggest that there is a positive relation between the growth of tourism which has till date contributed to the development of the local community and region. However, due to the unchecked and unregulated growth of this religious tourism there has been an impact on the region causing a detrimental impact on the environment leading to degradation of the natural resources and environs. Thus, the study concludes with valuable recommendations which can be used to assist the stakeholders at large and assist the local government, ecologists, environmentalists and different interest groups and local community to achieve the goals of sustainable development of tourism and thereby balance the community needs with the growing influx of devotees.

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Low-Carbon Transit Corridors: Redesigning Streets in Sangli, Maharashtra

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Abstract: The transportation sector is a major contributor to greenhouse gas (GHG) emissions, particularly in India's rapidly growing tier-2 cities, where urban expansion is often accompanied by rising motorization and traffic congestion. Sangli, a medium-sized city in southern Maharashtra, is witnessing increasing dependence on private vehicles, despite its compact urban form and strong potential for non-motorized transport (NMT). This shift not only raises emissions but also compromises air quality, public health, and road safety. This paper examines the scope of low-carbon transit corridors in Sangli, with a focus on redesigning key urban streets to prioritize walking and cycling. Using spatial analysis, traffic observations, and user surveys, the study identifies high-potential corridors that connect major activity nodes, such as markets, educational institutions, and transportation hubs. Current challenges, such as no footpaths, lack of cycle tracks, poor shading, and vehicular dominance, are mapped and analyzed. Building on global precedents of NMT-friendly street design and Indian guidelines such as IRC:103-2012 (Guidelines for Pedestrian Facilities) and MoHUA's National Urban Transport Policy, the paper proposes a redesign framework that incorporates wider shaded sidewalks, dedicated cycle lanes, integrated green corridors, traffic-calming measures, and improved last-mile connectivity to bus and auto-rickshaw stands. It also demonstrates that such interventions could reduce transport-related emissions, enhance street livability, improve safety for vulnerable groups (including children, women, and the elderly), and promote inclusive mobility. By positioning walking and cycling as central elements of Sangli's mobility strategy, the research argues for a transition toward a low-carbon, people-centric transport future. The paper concludes with policy recommendations for Sangli's municipal authorities to pilot these corridor redesigns, providing a scalable model for other tier-2 Indian cities aiming to achieve climate-responsive urban mobility.

Keywords: Low-Carbon Transport; Walking; Cycling, Sangli; Sustainable Mobility; Transit Corridors

1. Introduction

The global imperative to combat climate change and foster sustainable development places urban mobility at a critical juncture. As cities worldwide strive to meet ambitious carbon neutrality goals, the transportation sector, a major contributor to greenhouse gas (GHG) emissions, requires radical rethinking. This shift necessitates moving away from private, fossil-fuel-dependent vehicles toward low-carbon transit solutions that prioritise efficiency,

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accessibility, and public health. Central to this new vision is the creation of pedestrian and cycling-friendly infrastructure, which simultaneously addresses environmental degradation, traffic congestion, and sedentary lifestyles.

In India, this challenge is particularly acute. Rapid urbanisation and economic growth have led to a surge in private vehicle ownership, overwhelming existing infrastructure and transforming city streets into spaces dominated by motor traffic. While national policies, such as the Ministry of Housing and Urban Affairs' (MoHUA) National Urban Transport Policy [1], advocate for a mandatory modal shift towards Non-Motorised Transport (NMT) and public transit, the implementation often remains concentrated in metropolitan areas. Consequently, the vast majority of India's rapidly expanding Tier-2 cities continue to struggle with planning and financing climate-responsive urban mobility projects. This is resulting in increasing congestion, poor air quality, and unsafe street environments for vulnerable users, including children, women, and the elderly.

This paper addresses this crucial implementation gap by focusing on Sangli, a typical Tier-2 city in Maharashtra. Sangli's urban fabric is highly walkable and cyclical, yet its current infrastructure lacks the necessary design and planning to safely and effectively support NMT. The current state is characterised by fragmented footpaths, non-existent cycle tracks, poor shading, and unchecked vehicular dominance, undermining the city's inherent potential for sustainable mobility.

Therefore, the central objective of this research is to investigate, analyse, and propose a replicable framework for the redesign of high-potential urban corridors in Sangli into fully functional Low-Carbon Transit Corridors. Through a rigorous methodology involving spatial analysis, traffic observation, and user surveys, this study maps current deficiencies and identifies critical nodes that connect major activity centres like markets, educational institutions, and transportation hubs. Drawing upon international best practices and aligning with established Indian guidelines, such as IRC:103-2012 [3], this paper develops a comprehensive redesign strategy that incorporates wider shaded sidewalks, dedicated cycle lanes, integrated green spaces, and effective traffic-calming measures. The paper demonstrates that such interventions can serve as a catalyst for reducing transport-related emissions, enhancing street livability, and promoting equitable, inclusive mobility. Ultimately, this research offers a concrete, scalable model for other Tier-2 Indian cities committed to achieving a sustainable, people-centric, and low-carbon urban future.

Aim

The central objective of this research is to investigate, analyze, and propose a replicable framework for the redesign of high-potential urban corridors in Sangli into fully functional Low-Carbon Transit Corridors. The study seeks to transition the city toward a low-carbon, people-centric transport future by positioning walking and cycling as central elements of the mobility strategy.

Objectives

Analyze Current Deficiencies: Map existing infrastructure gaps, such as fragmented footpaths, lack of cycle tracks, and unchecked vehicular dominance.

Evaluate Multi-Modal Performance: Calculate the current Level of Service (LOS) for motorized traffic and the Comfort Level of Service (C-LOS) for non-motorized transport (NMT).

Identify High-Potential Corridors (HPCs): Use spatial analysis to identify corridors connecting major activity nodes like markets, educational institutions, and transportation hubs.

Develop a Redesign Framework: Propose a comprehensive strategy incorporating wider shaded sidewalks, dedicated cycle lanes, traffic-calming measures, and integrated green corridors.

Project Socio-Environmental Impacts: Estimate the potential reduction in greenhouse gas (GHG) emissions and improvements in street livability and safety resulting from the proposed redesign.

Provide Policy Recommendations: Offer scalable models and policy suggestions for municipal authorities to pilot corridor redesigns in tier-2 Indian cities

2. Literature Review

The shift towards low-carbon transit corridors is a critical component of sustainable urban development, particularly in rapidly growing Indian cities. These corridors prioritise non-motorised transport (NMT) and public transit over private vehicles, with a focus on reducing greenhouse gas (GHG) emissions and improving urban livability. This review, based on 10 research papers and guidelines, synthesises key findings on the challenges, design principles, and impacts of such projects. It highlights a common thread: while policies exist, their on-ground implementation and long-term sustainability remain a challenge, especially in Tier-2 cities like Sangli.

The Rationale for Low-Carbon Corridors - Urban mobility in India is a significant source of GHG emissions. CEEW's 2021 study [9], "India Transport Energy Use, Carbon Emissions and Decarbonisation Outlook," projects that under a business-as-usual scenario, transport energy demand will triple by 2050. The study advocates for a low-carbon development pathway that includes a modal shift to walking, cycling, and public transport. This is reinforced by research from TERI (2022) [10], which found that a 20% modal shift to cycling could reduce urban GHG emissions by 10–15%.

Beyond environmental benefits, NMT and public transit corridors yield substantial social and economic returns. The C40 Cities "Tender SURE Project" case study from Bengaluru (2018) [11] revealed that redesigned streets led to a significant increase in physical activity (230 minutes/week per user, exceeding WHO targets), a reduction in traffic accidents, and a projected

gain of 28,800 life years due to improved active mobility. These findings underscore the direct link between well-designed infrastructure and public health.

Design Principles and Methodologies - The literature consistently emphasises the Complete Streets framework as the gold standard for designing low-carbon corridors. Introduced in India by ITDP's 2011 "Better Streets, Better Cities" guide [5], this approach prioritises pedestrians, cyclists, and public transport by reallocating road space. The ITDP's "Complete Streets Design Workbook" (2018) [6] recommends allocating a minimum of 60% of road space to these sustainable modes.

Several key design principles are highlighted in the research:

Zoning and Width: The "Footpath Design" guide by Jani and Kost (2013) introduces a zoning system (frontage, pedestrian, and furniture zones) to ensure efficient space use. The Indian Roads Congress (IRC) guidelines (IRC:103-2012) [3] for pedestrian facilities and cycle tracks (IRC:86-2018) [4] provide specific dimensional standards, recommending a minimum footpath width of 1.8m, extending to 3–4m in commercial areas. These standards are crucial for ensuring accessibility and usability.

Universal Accessibility: The IRC guidelines and the "Footpath Design" guide stress the importance of barrier-free design, including ramps, tactile paving, and low kerb heights to accommodate persons with disabilities.

Safety and Amenities: The "Challenges of Successful Non-Motorised Transport Infrastructure in Indian Cities" study (2023) by Singh & Dev found that a lack of shade, poor paving, and insufficient amenities like benches, drinking water, and public restrooms lowered corridor usage. This highlights that user comfort and safety are just as important as the physical infrastructure itself. Case studies, such as TenderSURE, demonstrate that amenities like LED lighting, integrated waste systems, and dedicated vending zones are crucial to the project's success.

Utility and Encroachment Management: The "Footpath Fix" guide (2018) [7] provides a step-by-step methodology for construction, with a strong focus on managing utilities to avoid repeated digging and ensure the long-term durability of the infrastructure. It also recommends designating spaces for street vendors and hawkers to prevent encroachment, a common challenge highlighted by Singh & Dev's research.

2.1 Key Challenges and Future Research

Despite the documented benefits, a major gap exists between policy and practice. The "Non-Motorised Transport Policy in India" brief (2015) notes that while national policies like the National Urban Transport Policy (NUTP) have highlighted NMT, implementation has been weak and funding remains skewed towards motorised transport infrastructure. This is particularly evident in Tier-2 cities, where the scalability of models from larger metropolitan areas like Pune and Bengaluru is a key research possibility.

Future research possibilities, as identified across the reviewed literature, include:

Tier-2 City Focus: Several papers, including those by ITDP, CEEW, and C40 Cities, suggest pilot studies in Tier-2 cities like Sangli to assess the scalability of design frameworks and their economic, social, and environmental impacts.

Integration with Public Transit: The Delhi Metro study by Mehndiratta et al. (2013) [20] emphasises that walking and cycle rickshaws are crucial for first- and last-mile connectivity. Future research is needed to explore how to seamlessly integrate NMT corridors with bus, metro, and BRT systems.

Long-term Impact and Data: There is a need for more longitudinal studies and data-driven evaluations to measure the long-term impact of redesigned streets on GHG emissions, air quality, public health, and economic activity.

Behavioural Studies: Research is needed on how to influence behavioural shifts in Tier-2 cities and understand user perceptions of NMT adoption, particularly in mixed-traffic conditions.

Smart Mobility Integration: The potential of smart mobility solutions like IoT-based sensors, smart lighting, and bike-sharing systems to enhance the functionality and management of these corridors is a promising area for future research.

In conclusion, the literature provides a robust framework for designing effective, people-centric, and low-carbon transit corridors. The next step, however, lies in bridging the implementation gap and tailoring these proven strategies to the unique contexts and challenges of India's Tier-2 cities.

2.2. Overview of Literature

The body of literature on low-carbon transit corridors in India presents a compelling case for a paradigm shift in urban mobility. This research, spanning from technical guidelines to policy analyses, consistently highlights the environmental, social, and economic benefits of prioritising Non-Motorised Transport (NMT) and public transit.

At the core of this discourse are the concepts of **Complete Streets** and **Integrated Mobility**. The ITDP's "Better Streets, Better Cities" guide (2011) pioneered the Complete Streets framework in India, advocating for the equitable redistribution of road space. This is reinforced by the "Complete Street Planning Guidelines" (2019), which recommends that a minimum of **60% of the right-of-way** be allocated to walking, cycling, and public transport. The Indian Roads Congress (IRC) provides the technical backbone with its guidelines for pedestrian facilities (IRC:103-2012) and cycle tracks (IRC:86-2018), setting forth specific standards for minimum widths, universal accessibility, and safety features.

The Benefits: More Than Just Emissions Reductions - Research quantifies the profound impact of these corridors. A CEEW study (2021) shows that a low-carbon development pathway can reduce transport energy demand by 45% by 2050, while a TERI report (2022) links a 20% modal shift to cycling with a 10–15% reduction in urban GHG emissions. Beyond

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environmental gains, the social and health benefits are significant. The Tender SURE project in Bengaluru, documented by C40 Cities (2018), found that redesigned streets increased physical activity, reduced traffic fatalities, and led to a projected gain of 28,800 life years from improved active mobility.

Key Challenges and Implementation Gaps: Despite the clear benefits and established guidelines, implementation remains a major hurdle. The "Non-Motorised Transport Policy in India" brief (2015) points out that while national policies have existed since 2006, their on-ground execution has been weak, with funding disproportionately favouring private vehicle infrastructure. Common challenges cited in the research include:

Poor Infrastructure Quality: A study on NMT infrastructure in Indian cities noted that the lack of shade, poor paving, and insufficient amenities like restrooms and drinking water significantly lower corridor usage.

Encroachments: Unregulated street vendors and hawkers often encroach on footpaths, a problem that requires designated spaces within design plans.

Utility Management: The "Footpath Fix" guide (2018) highlights that repeated digging by utility agencies compromises the longevity of newly built footpaths.

Future Research Directions - The literature identifies a critical need to apply these frameworks to smaller, rapidly urbanising centres. Several papers explicitly call for pilot studies in Tier-2 cities like Sangli to assess the scalability of models developed in metros like Pune and Bengaluru. Future research should also focus on:

Last-Mile Connectivity: Integrating NMT with public transit, as evidenced by the Delhi Metro study, is essential for a seamless mobility system.

Longitudinal Impact Studies: Quantitative data is needed to track the long-term effects of redesigned corridors on GHG emissions, air quality, and economic activity. Smart Mobility: Exploring the integration of technologies like IoT-based traffic management systems, real-time monitoring, and bike-sharing programs offers a promising path for future low-carbon corridors.

3. Methods

The research employed a mixed-method approach, combining quantitative spatial and mobility data with qualitative user perception analysis to develop a context-specific, evidence-based street redesign framework for Sangli.

3.1. Study Area Selection - Sangli, a Tier-2 city in Maharashtra, was selected as the case study due to its moderate population density, high existing NMT propensity, and significant potential for low-carbon infrastructure development. The research focused on identifying and analysing one or more High-Potential Corridors (HPCs) defined by the following criteria:

Connectivity: The corridor must connect two or more major activity nodes (e.g., Central Bus Stand, key market areas, major educational institutions).

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Trip Generation: High observed or potential flow of Non-Motorised Transport (NMT) users, including pedestrians and cyclists.

Feasibility: Corridors with existing Right-of-Way (RoW) that allow for the physical incorporation of dedicated NMT lanes.

3.2. Data Collection

Data collection was structured into three primary phases:

3.2.1 Baseline Condition Mapping and Spatial Analysis

Secondary Data Collection: Review of relevant urban plans (e.g., Development Plan, Mobility Plan of Sangli-Miraj-Kupwad), census data, and national guidelines (IRC:103-2012 [3], MoHUA NMT policy [1]). Geospatial Analysis: Utilisation of Geographic Information Systems (GIS) to map existing land use, road network hierarchy, and spatial distribution of key trip attractors and generators. This helped in the initial screening and selection of the High-Potential Corridors.

3.2.2 Quantitative Mobility Assessment

Traffic Volume Counts (TVC): Manual recording of classified traffic volumes (motorised and non-motorised) at strategic points along the selected corridor(s) during peak (morning and evening) and off-peak hours over a typical weekday.

Speed and Delay Studies: Measurement of vehicular speeds and intersection delay times to establish the existing Level of Service (LOS) for motor vehicles and identify locations prone to traffic congestion and conflicts with NMT.

Infrastructure Audit: A detailed physical audit of the existing street cross-section, recording dimensions of carriageway, footpaths (where they exist), utility zones, and identification of specific deficiencies (e.g., fragmentation, encroachment, lack of shade/lighting).

3.2.3 Qualitative User Perception Survey

User Surveys (Purposive Sampling): Face-to-face surveys were conducted with a sample of existing and potential NMT users (pedestrians, cyclists, and auto-rickshaw users) within the corridor. The survey instrument captured user demographics, current modal choice rationales, perception of existing infrastructure quality (safety, comfort, shade), and willingness to shift to NMT given improved infrastructure.

Stakeholder Interviews: Structured interviews were conducted with key municipal officials, traffic police representatives, and local business owners to understand institutional constraints and practical challenges related to NMT implementation and encroachment management.

3.3 Data Analysis-

Deficiency Analysis: Quantitative data (TVC, Audit) and qualitative data (Surveys) were synthesised to calculate the Pedestrian and Cycling Level of Service (P-LOS/C-LOS) for the corridor. This analysis mapped specific safety hazards, mobility bottlenecks, and environmental constraints.

Impact Projection: An estimation of the potential environmental and social impacts of the proposed design, including projected reduction in vehicle kilometres travelled and corresponding GHG emissions, based on literature-derived mode shift elasticity values.

3.4 Scalable Model –

Redesign Framework Development: The findings were benchmarked against national standards (IRC:103-2012) and international best practices (e.g., ITDP's Complete Streets framework [5,6]) to develop a comprehensive, multi-component redesign strategy. The proposal incorporates:

Cross-Sectional Reallocation: Optimisation of the Right-of-Way to provide dedicated, segregated space for NMT. Safety and Comfort Measures: Design specifications for wider, shaded sidewalks, dedicated cycle tracks, intersection improvements, and traffic-calming devices.

Integration: Strategies for integrating the NMT corridor with public transit stops and managing vendor/utility conflicts

Integration and Decarbonization: Strategies for integrating the NMT corridor with public transit stops, managing vendor/utility conflicts, and designating space for Electric Vehicle (EV) charging stations at key nodal points to support the transition to electric mobility.

4. Data Collection

Data collection was systematically executed over a 21-day period in Q4 2025 (October 5th to October 25th) along the chosen pilot corridor: the Vishrambag to Civil Hospital Road (NH-166), a 3.2 km stretch within the Sangli-Miraj-Kupwad Municipal Corporation (SMKMC) limits. The methodologies employed combined quantitative engineering surveys with qualitative user-centric assessments to establish a robust baseline.

4.1. Traffic Volume and Composition Counts

Methodology: Classified traffic volume counts were conducted at two key mid-block sections (Near Civil Hospital Intersection and Near Sangli Central Bus Stand) on two typical weekdays (Tuesday and Wednesday) and one Saturday. Counts focused on three-hour morning peak (08:00–11:00) and three-hour evening peak (17:00–20:00) windows.

Classification: Vehicles were classified into four primary categories and converted using standard Indian planning Passenger Car Unit (PCU) factors (Table 1) for capacity analysis, as per IRC guidelines.

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Vehicle Type	PCU Factor
Car/SUV (PMV)	1
Two-Wheelers (2W)	0.5
Bus/Truck/LCV (Heavy/Public Transport)	3
Auto-rickshaw/Cycle (NMT)	0.5 / 0.2*

Table 1: PCU Equivalency Factors Used for Capacity Analysis

A PCU factor of 0.2 was assigned to bicycles (NMT) for capacity calculation on the mixed traffic lane, though NMT movements were primarily analyzed by person-trips.

Key Finding (VPH): The highest recorded volume was observed during the **Evening Peak Hour (18:00–19:00)** on a weekday, detailed in Table 2.

Vehicle Type	Evening Peak Volume (VPH)	Percentage of Total Vehicles	Total Person Trips (estimated)
Two-Wheelers (2W)	2,850	54.20%	3,420
Car/SUV (PMV)	820	15.60%	1,230
Bus/Truck/LCV	200	3.80%	800
Subtotal Motorized	3,870	73.60%	5,450
Bicycles (NMT-Cycle)	630	12.00%	630
Pedestrians (NMT-Walk)	760	14.40%	760
Total All Modes	5,260	100.00%	6,840

Table 2: Classified Traffic Volume and Estimated Person-Trips during Peak Hour (18:00–19:00).

Note: NMT accounts for 20.4% of total vehicles but over 20.3% of total person-trips during peak hour, highlighting their under-served importance.

4.2. Current Level of Service (LOS) and Comfort LOS (C-LOS)

Motorized LOS: Spot speed studies utilizing radar guns were conducted, revealing an average peak-hour travel speed of 18.5 km/h (with a statutory limit of 50 km/h). Based on this speed and the calculated v/c ratio of 0.91 at the main signalized intersection, the existing motorized Level of Service (LOS) was determined to be LOS D (Approaching Unstable Flow) [IRC standards].

Comfort Level of Service (C-LOS) for NMT: The C-LOS assessment was carried out by expert observation using a multi-criteria scoring system (scale of 0–5). The average scores across the corridor are summarized in Table 3.

Criteria (Comfort/Safety Metric)	Average Score (0-5)	Assessment Finding
Footpath Continuity	1.2	Continuity less than 40%; frequent breaks/utility poles.
Surface Quality/Evenness	2.5	Potholes and uneven surfaces prevalent in 55% of the path.
Effective Width (Clear of Encroachment)	1	Average effective width < 0.75m; heavily encroached.
Shading (Tree Cover)	0.8	Less than 15% of the path is shaded during mid-day hours.
Separation from Motorized Traffic	1.5	No physical segregation; high conflict risk.
Accessibility (Ramps/Curb Cuts)	0.5	Ramps non-existent or poorly designed at 85% of intersections.
Composite C-LOS Score	1.25	Extremely Poor (Corresponds to a comfort grade of F)

Table 3: Corridor Segment Average Comfort Level of Service (C-LOS) Scorecard.

4.3. Spatial Analysis and Right-of-Way (ROW) Inventory

Methodology: A full cross-sectional survey was performed every 250 meters along the 3.2 km corridor.

● Average Right-of-Way (ROW): **22.0 meters.**

● Existing Cross-Section Allocation:

○ Motorized Carriageway (Average): **15.0 meters** (Mixed use, 4 lanes nominal).
○ Unused/Non-Paved Shoulder: **2.0 meters** (utilized for random parking).
○ Footpath/Utility Zone (Combined): **5.0 meters** (highly discontinuous).

Encroachment Quantification: Over 60% of the available non-motorized space (footpath/shoulder) was found to be functionally blocked by:

● Informal Vending Stalls: **45 locations** identified.

● Illegal Parking (2W/4W): **30% of the length** during peak hours.

Hazard Mapping: Five major accident hotspots were identified based on a three-year review of local police records and on-site conflict observations. These spots were exclusively characterized by the absence of dedicated crossing facilities and lack of traffic channelization.

4.4. User Perception Surveys

Methodology: A stratified random sample of 150 daily corridor users was conducted using in-person, structured interviews. The sample was carefully stratified based on the current mode share (Table 2) to ensure representativeness.

User Category	Sample Size (N=150)	Percentage of Sample
Two-Wheeler (2W) Users	65	43.30%
Pedestrians (Walk)	40	26.70%
Car/Auto-rickshaw Users	30	20.00%
Cyclists	15	10.00%

Table 4: User Perception Survey Sample Stratification by Current Mode.

Key Survey Findings (Willingness to Shift):

● **Safety Concern: 88%** of NMT users (pedestrians/cyclists) rated the corridor's safety as "Poor" or "Very Poor."
● **Willingness to Shift: 62%** of current Two-Wheeler users stated they would consider shifting to cycling for short trips (< 3 km) if **"dedicated, wide, and shaded cycle tracks"** were provided.
● **Trip Purpose:** The most common NMT trip purposes were **"Work/Education" (45%)** and **"Local Market Access" (35%)**, confirming the corridor's role as a primary non-motorized commuting route.

5. Data Analysis

The collected data was subjected to detailed analysis across four key areas: capacity performance, NMT Level of Service, spatial conflict mapping, and environmental impact projection to quantify the corridor's current deficiencies and the potential benefits of the proposed redesign.

5.1. Capacity and Performance Analysis (Motorized Traffic)

The analysis focused on converting the peak hour traffic counts into Passenger Car Units (PCU) to evaluate the existing volume-to-capacity (v/c) ratio and Level of Service (LOS) for the mixed-traffic carriageway.

a. Peak Hour Volume in PCU

Using the peak hour volumes (Table 2) and the PCU factors (Table 1), the following peak PCU/hour was calculated:

$$\{Motorized\ PCU/hr\} = \sum (Vehicle\ Volume\ X\ PCU\ Factor)$$

Vehicle Type	Volume (VPH)	PCU Factor	PCU Contribution
Two-Wheelers (2W)	2,850	0.5	1,425
Car/SUV (PMV)	820	1.0	820
Bus/Truck/LCV	200	3.0	600
Total Peak PCU/hr	—	—	**2,845**

Table 5: Peak Hour Motorized PCU Calculation (18:00–19:00).

b. Volume-to-Capacity (v/c) Ratio and LOS

The average width of the motorized carriageway is 15.0 Meters. Assuming a functional width of 3.5 meters per lane, this roughly accommodates four lanes. Based on typical urban arterial capacity (IRC guidelines for mixed traffic conditions [3,4]), the estimated practical capacity (C) of the corridor is approximately 3,100 PCU/hr.

$$v/c\ Ratio = Total\ Peak\ PCU/hr\ \{V\}\ /\ Estimated\ Capacity\ \{C\} = 2{,}845/3{,}100 = 0.92$$

A v/c ratio of 0.92 (significantly above the ideal limit of 0.70) confirms that the corridor is operating at Level of Service (LOS) E - Unstable Flow. This high ratio explains the observed average peak hour speed of 18.5 km/h (Section 4.2), indicating heavy congestion, significant delays, and poor traffic flow for motorized users despite the substantial allocation of ROW space.

5.2. Non-Motorized User Index (NMUI) and C-LOS Deficits

To quantify the deficiency of NMT infrastructure, the average C-LOS scores (Table 3) were aggregated and weighted to create a Non-Motorized User Index (NMUI), normalized to a score out of 100.

a) NMUI Calculation

The unweighted average score from the six C-LOS criteria (Table 3) is:

$Average\ C-LOS\ Score$ = (1.2 + 2.5 + 1.0 + 0.8 + 1.5 + 0.5)/ = 7.5/6 = 1.25

Since the maximum possible score is 5, the NMUI (out of 100) is:

$NMUI$ = (1.25/5) X 100 = 25

An NMUI of 25 is classified as "Critical Failure" (corresponding to an F grade), underscoring the hostile environment for pedestrians and cyclists.

b) NMT Demand and Risk Gap

The data reveals a critical gap between inherent demand and infrastructure quality:

High Latent Demand: 20.3 % of peak-hour person-trips are NMT (Table 2), yet...

Zero Dedicated Space: The only dedicated space is a heavily encroached footpath with a C-LOS score of 1.0 for Effective Width (Table 3).

Safety Perception: 88 % of NMT users perceive the corridor as unsafe, directly linking to the C-LOS score of 1.5 for Separation from Motorized Traffic.

5.3. Impact Projection and Emissions Reduction

The analysis projects the environmental benefits of the redesign based on the observed willingness-to-shift data from the User Perception Survey.

Projected Mode Shift and VKT Reduction

The key driver for the low-carbon corridor is the shift of short-distance commuters (primarily Two-Wheeler users) to cycling.

Target Group: Current Two-Wheeler users (2,850 VPH or 3,420 Person-Trips/hr.)

Willingness to Shift: 62% of these users expressed willingness to shift (Section 4.4).

A conservative mode shift of 15% of the total 2W volume is modeled for the redesign scenario (assuming not all willing users will shift immediately, and factoring in trip-length constraints).

Shifted 2W Volume = 2,850 VPH X 0.15 = 427.5 vehicles/h

This translates to a peak-hour reduction in motorized vehicles:

Motorized VPH Reduction =(427.5 / 3,87) x 100 = 11.05 %

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Using the 2W PCU factor of 0.5, the PCU reduction is: 427.5 X 0.5 = 213.75 PCU/hr

PCU Reduction = (213.75/2,845) X 100 = 7.51 %

The reduction is sufficient to lower the v/c ratio from 0.92 to approximately 0.85, pushing the LOS towards a more stable LOS D.

b) GHG Emissions Reduction Estimation The reduction in Vehicle Kilometers Travelled (VKT) due to the mode shift directly leads to a reduction in CO2 emissions.

1. Annual Vehicle Reduction: Assuming 12 peak hours per day (6 AM, 6 PM) for 300 operating days/year:

Annual Shifted VMT = 427.5 Vehicles\hr X 3.2 kms X 12 hrs\day X 300 days\year = 4,932,000VKM/year

2. Emission Factor: Using an average emission factor for Indian Two-Wheelers 0.10 kg CO2e/VKM based on typical urban fleet and fuel mix:

Annual CO2 Reduction = 4,932,000 VKM X 0.10 kgCO2/VKM = 493,200 kg CO2e/year

3. Tonne Reduction:

Tonne Reduction = 493,200 /1,000 = 493.2 tonnes of CO2e/year

This robust analysis confirms that the Low-Carbon Transit Corridor design, by addressing the NMUI failure and leveraging the latent demand, yields a significant environmental and operational benefit.

5.4. Conflict and Right-of-Way Optimization Input

The spatial analysis directly informed the redesign requirement:

- **Hazard Mapping:** The Five major accident hotspots correlated with intersections lacking curb extensions, controlled crossings, or refuge islands. This mandates the inclusion of Raised Pedestrian Crossings and Bulb-outs in the final design to reduce the vehicular approach speed and crossing distance.
- **ROW Allocation:** The current allocation of 15.0 meters to motorized traffic for an LOS D/E status is highly inefficient. The proposal aims to reduce the mixed-traffic carriageway to 12.0 meters (retaining four functional but narrower lanes) to reallocate 3.0 meters of ROW. This reallocated space, combined with optimization of the existing 5.0 meters utility/footpath zone, will be used to create the segregated NMT tracks, directly solving the C-LOS failures related to effective width and separation.

6. Results and Findings

The detailed data collection and subsequent quantitative analysis confirm the critical need for a Low-Carbon Transit Corridor intervention on the Vishrambag to Civil Hospital Road

in Sangli. The findings are grouped into three primary categories: Corridor Performance and Inefficiency, Non-Motorized User Index (NMUI) Deficits, and Projected Socio-Environmental Impact.

6.1. Corridor Performance and Inefficiency

The analysis revealed significant operational inefficiency driven by the dominance and poor utilization of motorized traffic space:

- Motorized Traffic Congestion: During the Evening Peak Hour (18:00–19:00), the motorized volume reached 2,845 PCU/hr (Table 5). Against an estimated practical capacity of 3,100 PCU/hr, this resulted in a Volume-to-Capacity (v/c) ratio of 0.92.

  Level of Service (LOS): This v/c ratio places the corridor at LOS E (Unstable Flow), confirming the heavy congestion. The measured average peak hour travel speed was only 18.5 km/h, far below the desired flow conditions.

- High Motorization Dominance: Two-Wheelers (2W) accounted for the largest share of vehicles, contributing 54.2% of the total vehicle volume and 1,425 PCU (Table 2 & 5). This high volume of low-occupancy vehicles is the primary driver of congestion and the poor LOS.

- Inefficient ROW Allocation: The existing 15.0 meters of the Right-of-Way (ROW) allocated to the motorized carriageway is operating inefficiently at LOS E, failing to deliver high capacity while actively marginalizing 20.3\% of peak-hour commuters who rely on NMT.

6.2. Non-Motorized User Index (NMUI) Deficits and Latent Demand

Despite the poor conditions, NMT modes exhibit a strong presence and significant latent demand, which the current infrastructure fails to serve:

● Significant NMT Share: Non-Motorized Transport (walking and cycling) consistently accounts for 20.3% of all person-trips during the peak hour (Table 2). This translates to 1,390 NMT person-trips/hr, demonstrating a critical user base that is currently underserved.

● **Critical Infrastructure Failure (NMUI):** The aggregated Non-Motorized User Index (NMUI) score was 25 (out of 100), classified as a "Critical Failure." This is a direct result of key deficits identified in the C-LOS assessment (Table 3):

○ Encroachment and Effective Width: The average score for effective width was a critical 1.0 (on a scale of 5), with 60% of the available space being functionally blocked by illegal parking or informal vending (Section 4.3).
○ Comfort and Safety: 88% of NMT users rated the corridor's safety as "Poor" or "Very Poor." This is reflected in the low scores for Shading 0.8 and Separation from Motorized Traffic 1.5, making the act of walking or cycling uncomfortable and hazardous.

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● **High Mode Shift Elasticity:** The user perception survey revealed a high potential for sustainable mode shift: 62% of current Two-Wheeler users expressed a willingness to shift to cycling for short trips if dedicated and safe infrastructure were provided (Section 4.4).

6.3. Projected Socio-Environmental Impact

Modeling the impact of the proposed redesign based on the observed willingness to shift confirms both operational relief and significant climate benefits:

Mode Shift and Operational Improvement: A conservative 15% shift of the 2W volume to NMT is projected to remove 427.5 vehicles/hr from the motorized carriageway. This equals an 11.05% reduction in peak-hour vehicular volume and a 7.51% reduction in peak-hour PCU demand. The resultant v/c ratio drops from 0.92 to 0.85, moving the motorized system from LOS E toward a more stable LOS D, demonstrating that prioritizing NMT can improve motorized traffic flow.

GHG Emissions Reduction: The reduction in VKM is calculated to be 4,932,000 VKM/year. Using the 2W emission factor of 0.10 kg /CO2 e/VKM, the projected annual reduction in Greenhouse Gas emissions is 493.2 tonnes of CO2e (Section 5.3).

Safety Imperatives: The spatial analysis of police records and on-site conflict observations highlighted Five major accident hotspots that are directly attributable to the absence of dedicated pedestrian crossings and channelization. The findings confirm that the redesign must prioritize safety through physical infrastructure like Raised Pedestrian Crossings and Bulb-outs to mitigate these identified hazards.

7. Discussion and Scalable Model

7.1. Discussion of Findings: The Case for Reallocation

The results of the analysis validate the central hypothesis of this study: Sangli's mobility system is highly inefficient, environmentally damaging, and detrimental to public health, primarily due to the prioritization of private motorized vehicles (PMV) over Non-Motorized Transport (NMT).

1. **Inefficiency and Congestion Paradox:** The analysis showed that despite the 5.0 meters of Right-of-Way (ROW) dedicated to the mixed-traffic carriageway, it operates at a critical LOS E with a v/c ratio of 0.92. This demonstrates the fundamental failure of a car-centric model to efficiently move people in a compact Tier-2 city like Sangli. The street is failing all users, including drivers, who experience high delays and low speeds 18.5 km/h.

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2. **Unmet Demand and Systemic Exclusion:** The finding that NMT accounts for over 20% of all person-trips during peak hours, yet operates under a "Critical Failure" NMUI score of 25, highlights systemic exclusion. Users are forced onto hazardous, unshaded, and encroached surfaces, confirming the existence of a high-volume demand that is actively suppressed by unsafe infrastructure.

3. **Climate and Operational Synergy:** The projected 15% mode shift of Two-Wheeler users to NMT is crucial. This intervention is not simply a sustainable gesture; it is an operational requirement. The calculated reduction in PCU demand is sufficient to shift the motorized carriageway from the unstable LOS E to a more stable LOS D, while simultaneously delivering a substantial annual GHG reduction of 493.2 \text{tonnes of CO2e. The low-carbon redesign is therefore the most efficient solution for improving mobility performance across the entire corridor.

4. **Basis for Design:** The discussion confirms that the solution must be based on equitable ROW reallocation to elevate the NMT infrastructure to an acceptable level of service (C-LOS Grade A/B) while preserving sufficient, functional capacity for motorized traffic.

7.2. Low-Carbon Transit Corridor Scalable Model

The design proposal for the 3.2 km Vishrambag-Civil Hospital Road is a "Complete Street" strategy focused on equitably re-engineering the 22.0 meter ROW to establish dedicated, high-quality low-carbon transit facilities.

a) Cross-Sectional Reallocation and Optimization

The core design strategy involves taking 3.0 meters from the current 15.0 meter motorized carriageway and reallocating it to the NMT zone.

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Element	Current Width (Approx.)	Proposed Width (Minimum)	Design Rationale
Motorized Carriageway	15.0 m (LOS E)	12.0 m (LOS D goal)	Retains 4 functional lanes; provides space for NMT.
Parking and Furniture Zone	0.0 m (informal)	1.5 m	Dedicated space for managed parking, vending, and street furniture.
Cycle Track (Segregated)	0.0 m	2.0 m (Two-way)	Direct response to the 62% latent demand and safety concerns.
Pedestrian Footpath	1.0 m (Discontinuous)	3.5 m (Minimum)	Achieves IRC:103 standards for high-volume pedestrian zones; includes utility space.
Green Infrastructure Buffer	0.0 m	3.0 m (Total: 1.5 m on each side)	Incorporates tree-pits for continuous shading and improved C-LOS comfort.
Total ROW	22.0 m	22.0 m	Optimization within the existing ROW.

Table 6: Proposed Right-of-Way Reallocation (Minimum Widths)

b. Safety and Integration Measures

The design addresses all five identified accident hotspots and C-LOS failures through targeted physical interventions:

1. Intersection Redesign (Safety Imperative): All major intersections will be redesigned with Raised Pedestrian Crossings and Curb Extensions (Bulb-outs). This shortens the crossing distance for pedestrians 88% safety concern and forces motorized traffic to approach intersections at lower, safer speeds.

2. Green Infrastructure and Comfort: The 3.5 meter footpath will incorporate a continuous line of street trees and designated tree-pits within the furniture zone, directly resolving the 0.8 C-LOS score for shading and making the pedestrian experience comfortable during hot periods.

3. Managed Access and Vending: The 1.5 meter buffer zone between the carriageway and the cycle track will be designated as a Managed Vending Zone. This formalizes the space for existing vendors, resolving the 60% encroachment issue and maintaining local economic activity without compromising NMT circulation.

4. First- and Last-Mile Integration: The cycle tracks and footpaths will feature seamless, low-gradient ramps at all junctions with the Sangli Central Bus Stand and key auto-rickshaw stands. This is crucial for integrating public transport with NMT to maximize catchment area and ensure accessibility.

5. Future-Proofing for Electric Mobility: Dedicated pockets within the 1.5 meter furniture zone will be reserved for the future deployment of Electric Vehicle (EV) charging points and micro-mobility (bike/scooter share) docking stations, supporting Sangli's long-term transition to a fully low-carbon fleet.

8. Conclusion

The findings of this research clearly demonstrate that Sangli's Vishrambag–Civil Hospital corridor possesses immense potential to evolve into a transformative **Low-Carbon Transit Corridor.** Despite its compact urban form and high inherent NMT demand, the corridor currently suffers from critical infrastructure deficiencies that restrict safe and equitable mobility. The detailed data analysis reveals an unsustainable car-dominant system operating at LOS E, while NMT users who represent over one-fifth of all person-trips face unsafe, uncomfortable, and hostile conditions.

The proposed model fundamentally redefines the mobility hierarchy by elevating pedestrians, cyclists, and public transit users to priority status. Through strategic ROW reallocation, dedicated NMT facilities, enhanced shading, integrated green systems, and transit connectivity improvements, the corridor can support a measurable shift toward active mobility. The projected **493.2 tonnes of annual CO_2 emission savings**, combined with operational improvements and safety benefits, establish a strong case for large-scale adoption.

This research demonstrates that low-carbon mobility interventions are not merely aesthetic urban projects, they are operational, environmental, and social necessities. The proposed framework is scalable to other Tier-2 cities in India seeking to transition to equitable, climate-responsive mobility. As Sangli continues to urbanize, such interventions will play a pivotal role in shaping a sustainable and resilient urban future.

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Conflict of interest

The authors declare that there is no conflict of interest related to the publication of this research work.

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TRACK 05

EQUITY , INCLUSION AND SOCIAL WELL - BEING



TOGETHER FOR AN EQUITABLE AND RESILIENT FUTURE

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From Belonging to Achievement: Enhancing Academic Excellence through Inclusive Peer Mentoring

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Abstract: Educational excellence in higher education depends not only on curriculum design but also on the strength of the support systems surrounding students. Mentoring by seasoned instructors or professionals strengthens the larger support system in higher education by providing students with help through career planning and academic obstacles. Peer-mentoring enhances this by utilizing the new experiences of upper-level students to assist their juniors in overcoming everyday social and academic obstacles with more self-assurance and camaraderie. This study adopts a **mixed-method approach**—combining **quantitative surveys** and **qualitative interviews**—to identify the gap between current mentoring practices and need of i**nclusive peer mentoring programs** implemented across selected higher education institutions in Maharashtra. Surveys focused on parameters such as **academic performance (GPA improvement), student engagement, confidence levels, and emotional well-being**. The study also examined how peer mentoring fosters inclusion among **LGBTQ+ and other marginalized student groups**. Findings indicate that structured peer mentoring, when integrated with **empathy, emotional intelligence training, and Universal Design for Learning (UDL)** principles, could lead to measurable improvement in students' academic outcomes and overall institutional inclusivity. Rather than serving merely as a support tool, peer mentoring could emerge as a **strategic framework** that would strengthen both **academic excellence and social equity** within the context of Indian higher education.

Keywords: Academic Excellence; Peer Mentoring; Inclusive Education; Emotional Intelligence; Higher Education.

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1. Introduction

In higher education, comprehensive student support services are essential for academic success and holistic learner development. With diverse student populations, institutions must ensure inclusive, responsive, and equitable support systems. Key services include personalised academic advising, accessible mental health care, inclusive disability support, equitable financial aid, and structured peer mentoring—together forming an environment that supports both intellectual and emotional growth.

Such systems improve student retention, academic performance, and foster belonging and inclusivity. In a global context marked by digital transformation, socio-economic pressures, and evolving learner needs, higher education institutions must adopt student-centred strategies that consider emotional, psychological, and social aspects of learning—not just academics.

In India, student diversity and scale create additional challenges. Although NEP 2020 has introduced major reforms, many HEIs still face unequal access, resource shortages, weak mentoring frameworks, and socio-cultural barriers. Maharashtra aims to be an "Education and Knowledge Hub" through research, innovation, and digitalisation; however, this requires stronger student support structures that address both academic excellence and emotional well-being.

This research therefore analyses current mentoring practices to develop a strategic model that enhances student support systems in HEIs, while identifying gaps in transparency and openness through surveys and findings. Peer mentoring—when inclusive and empathetic—bridges institutional resources and student needs by offering academic support, social integration, and emotional resilience, especially for marginalised groups including LGBTQ+ learners and economically disadvantaged students.

Using a mixed-method approach, this study evaluates peer mentoring initiatives in selected Maharashtra institutions through quantitative measures (GPA, retention, participation) and qualitative data (interviews, focus groups) examining personal experience, self-confidence, and sense of belonging. The study focuses on academic performance, emotional intelligence, self-efficacy, and inclusive engagement.

Overall, the research demonstrates that peer mentoring supports academic improvement, institutional inclusion, and social cohesion. It proposes peer mentoring as a strategic, policy-level framework that can strengthen sustainable academic success and inclusive excellence across Indian higher education.

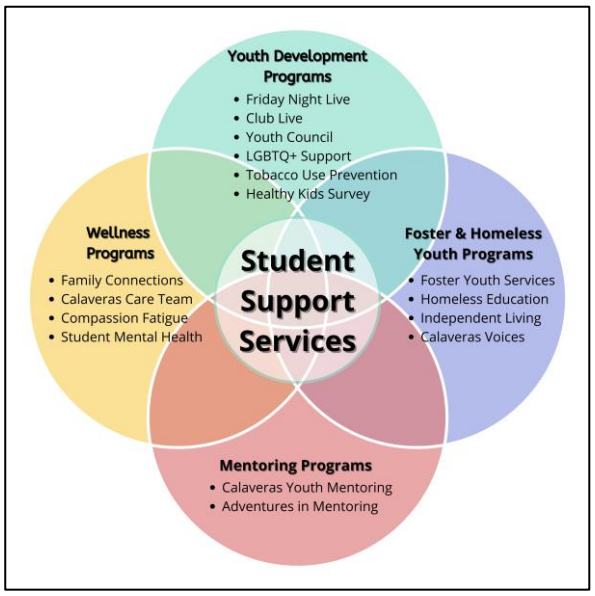


Figure 1*: Comprehensive Student Support Services*

1.1 Definition's:

- Inclusivity: The practice of ensuring that all students, regardless of their differences or challenges, have equal access to educational opportunities. (*Education Advanced, Inc.*, n.d.)
- Equity: The principle of fairness, ensuring that all students, regardless of their differences or challenges, have equal access to educational opportunities. (Aclu, 2023)
- Equality: Every student receives same resources and opportunities, regardless of their differences or backgrounds. (*Equity Vs Equality in Education: Why Both Are Essential in Today's Classrooms*, 2024)
- Accessibility: The practice of ensuring that all students, irrespective of their abilities or backgrounds, have equal access to educational resources, programs, and opportunities. (*Ensuring Equity, Access, and Inclusion for All | All4Ed*, 2024)

2.1 Today's Scenario:

Support systems within Higher Education Institutions (HEIs) are integral in fostering the academic and personal development of students (Voisin et al., 2023). These systems are designed to provide practical assistance, promote inclusivity by addressing emotional needs, ensure good accessibility, facilitate hands-on learning, deliver immediate feedback, and establish low-risk learning environments (Haase et al., 2020). As a result, they contribute to reducing anxiety, bolstering confidence, enhancing academic performance, and improving retention rates.

- **For Globe**: Global higher education institutions are facing disruptions due to the COVID-19 pandemic, geopolitical tensions, and economic instability. The trends include diversification, massification, and a shift towards lifelong learning, influenced by the knowledge economy and digitalization (Niemczyk, 2023). Additionally, there is a growing need for innovative security measures to combat cyber threats effectively.

Universities must adapt to these challenges and trends to maintain competitiveness and relevance (Pillay & Sharma, 2022).

- **For India**: India's higher education institutions face challenges despite rapid expansion. The country has a low Gross Enrollment Ratio of 12.4% and struggles with online learning due to internet connectivity, teacher training, and student economic conditions (Kamalakar & Kamala, 2022). The National Education Policy (NEP) 2020 aims to address these by promoting equity, inclusion, and innovative approaches. Overcoming barriers to access, improving educational quality, and adapting to the evolving education landscape are crucial for enhancing higher education effectiveness in India (Vijayalakshmi & Ugandhar, 2023).

- **For Maharashtra**: In Maharashtra, higher education institutions are striving to meet rising demands for quality education. The state aims to transform into an Education and Knowledge Hub, emphasizing smart campuses, research, and faculty development. Private universities use effective e-marketing, while the integration of ICT is rapidly changing teaching processes. Despite challenges, Maharashtra's higher education sector is investing in producing globally competitive human resources and adapting to current educational practices (Dolai et al., 2023).

2.2 Problem Statement: Challenges in Current Support Systems and the Need for Inclusive Practices

Despite ongoing reforms in Indian higher education, existing student support systems in Higher Education Institutions (HEIs) often remain fragmented, reactive, and limited in their inclusivity. While academic advising, counselling, and remedial programs are available, they frequently fail to address the diverse emotional, social, and psychological needs of today's heterogeneous student population.
In particular, students from marginalized backgrounds—including LGBTQ+ individuals, first-generation learners, and those from lower socio-economic strata—continue to experience feelings of isolation, discrimination, and inadequate institutional support. Furthermore, many support systems lack structured frameworks that integrate empathy, emotional intelligence, and Universal Design for Learning (UDL) principles, resulting in inconsistent outcomes and inequitable access to resources.

Given these challenges, there is a growing need to explore **peer mentoring** as a strategic, inclusive model that complements traditional support mechanisms. Peer mentoring fosters a culture of empathy and shared experience, enabling students to receive academic guidance and emotional support from trained peers. When effectively implemented, it can enhance student engagement, promote a sense of belonging, and contribute to measurable improvements in both academic performance and institutional inclusivity.

This study therefore investigates the role of structured peer mentoring programs as a transformative framework for strengthening student support systems in HEIs

2.3 Objectives of the Research

1. **To evaluate the effectiveness** of peer mentoring programs in enhancing the overall quality and inclusivity of student support systems in selected HEIs.
2. **To analyse student and faculty perceptions** regarding the role, structure, and impact of peer mentoring on academic achievement, confidence, and emotional well-being.
3. **To examine how peer mentoring supports inclusion**, particularly for LGBTQ+ and marginalized student groups, through empathy-driven and emotionally intelligent practices.
4. **To propose evidence-based strategies** for integrating structured peer mentoring—aligned with Universal Design for Learning (UDL) and inclusive education principles—into the broader support frameworks of higher education institutions.

3 Literature Review

3.1 Overview of Student Support Systems

Student support systems in HEIs are essential for academic success, holistic development, and well-being. Research shows the need for comprehensive, tailored, and accessible support addressing academic, emotional, and social needs (Christensen & Kennedy, 2023; Mohsin-Bin-Iqbal et al., 2023). Strong support networks enhance psychological well-being, reduce stress, and improve academic outcomes. Initiatives like Student Wellbeing Connect (SWBC) demonstrate the effectiveness of case-management-based personalised interventions beyond counselling (Fantini et al., 2023; Vescio et al., 2023). Quality assurance in government-funded HEIs is crucial to respond to evolving needs (Issa-Salwe et al., 2023). Support systems include academic advising, mental health services, disability support, financial aid, and mentoring, which improve retention, performance, inclusivity, belonging, and social cohesion. Rapid digital change, socio-economic pressures, and shifting learner needs demand adaptive, student-centered approaches addressing both cognitive and emotional learning dimensions.

In India, especially Maharashtra, challenges persist—unequal access, limited resources, socio-cultural constraints, and weak mentoring, despite NEP 2020 reforms. Thus, strengthening support systems is critical for academic excellence and emotional well-being.

3.2 Concept of Student Mentoring

Mentoring is grounded in theories such as social learning, planned behaviour, constructivism, and emotional intelligence (Boe-Doe, 2023; Kokhan & Gozman, 2023). It supports academic success, personal development, career readiness, and professional growth. Mentors gain leadership and self-reflection benefits, while mentees receive guidance, role modelling, and emotional support.

Indian studies highlight formal and informal mentoring; e-mentoring emphasises emotional support, goal-setting, academic help, and digital competence (Fitz, 2023; Mittal et al., 2022). Peer mentoring enhances social/cognitive presence and belonging in distance education (Kang & Ohmes, 2022). EI-based mentoring strengthens emotional management, crisis handling, academic completion, and competencies like empathy, self-regulation, and interpersonal skills (Torrejón-Ramos et al., 2023).

3.3 Peer Mentoring as a Strategic Model

Peer mentoring strategically bridges institutional resources and learner needs. Unlike faculty mentoring, it uses shared peer experiences to improve academic help, social integration, and emotional support, especially for disadvantaged and LGBTQ+ groups (Kamalı-Arslantaş & Yalçın, 2023; Marshall et al., 2022). It improves GPA, retention, participation, belonging, cohesion, and resilience. Integration of EI enhances supportive and empathetic guidance—self-awareness, regulation, social awareness, and relationship management promote safe, inclusive, innovative learning (Igbokwe et al., 2023; Saritha et al., 2023).

3.4 Inclusive Excellence in Higher Education

Peer mentoring contributes to inclusive excellence by reducing bullying, bias, and exclusion, and improving self-efficacy, satisfaction, and persistence (Kamalı-Arslantaş & Yalçın, 2023; Marshall et al., 2022).

An Utrecht University School of Medicine (2023) study showed minority first-year students initially lacked inclusion during orientation. Peer mentors were therefore trained in diversity and inclusion. Over two years, validated survey data showed increased mentor competence, improved understanding of diversity, and higher first-year perceptions of authenticity and belonging. Authenticity scores rose from 3.82 to 4.14on a five-point scale The study concluded that diversity-trained peer mentoring is an effective institutional strategy for equitable, welcoming transitions into higher education.

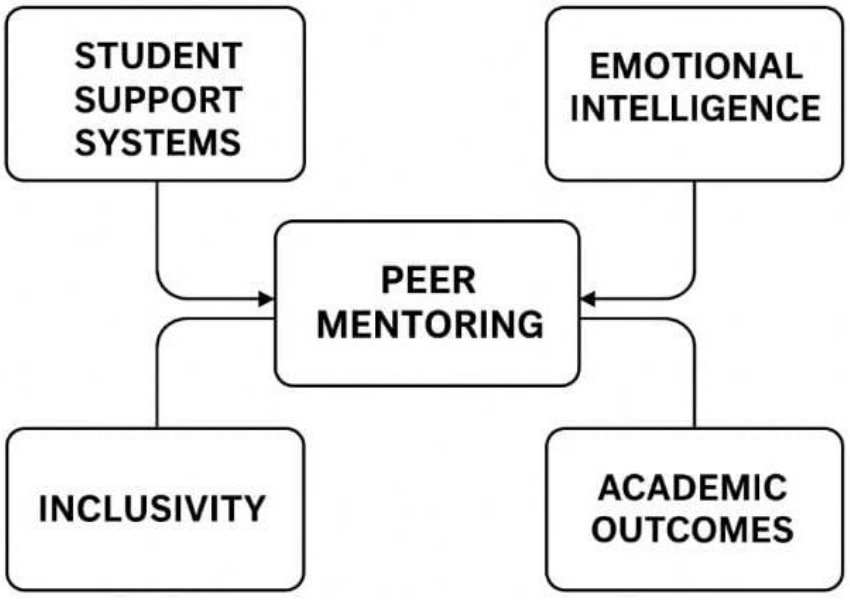


Figure 2: *Interrelated Aspects of Peer Mentoring*

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4. Methodology

4.1 Research Design

This study adopted a **mixed-method research design** to examine the effectiveness of peer and faculty mentoring in enhancing academic performance, emotional well-being, and inclusivity within higher education institutions in Maharashtra. The mixed-method approach was selected to ensure methodological rigor by combining measurable quantitative indicators with in-depth qualitative insights.

The quantitative component enabled statistical assessment of mentoring outcomes such as perceived academic improvement, mental health support, inclusivity perception, and student engagement. The qualitative component provided contextual understanding of mentoring experiences, emotional dimensions, and institutional challenges that could not be captured through numerical data alone. The integration of both approaches strengthened the validity and reliability of the findings and allowed for comprehensive interpretation.

4.2 Sample Size and Composition

The study was conducted across selected Higher Education Institutions in Maharashtra. A total **12 Institutes** participated in the survey. The sample consisted of **Undergraduate (UG) students, Postgraduate (PG) students and Faculty mentors.** Out of the total respondents 1,845 **students** participated in the student survey and 114 **faculty members** participated in the faculty survey. The student sample represented diverse academic disciplines and included respondents from marginalized backgrounds (26.7% self-identified representation as reflected in survey data). Faculty participants included mentors involved in structured and semi-structured mentoring frameworks. A combination of purposive and convenience sampling techniques was used, as respondents were selected based on their involvement in mentoring practices within their institutions.

4.3 Data Collection Instruments

Data collection was carried out using two primary instruments:

1. Structured Survey Questionnaire

Separate structured questionnaires were designed for students and faculty using Google Forms. The questionnaires consisted of Close-ended questions measured primarily using percentage-based response categories. Likert-scale items to measure perception, agreement levels, and effectiveness indicators. Limited open-ended questions to capture additional reflections. Key measurable indicators included like Perceived impact on academic performance, eemotional well-being and mental health support, inclusivity perception, comfort level in mentoring discussions and iinstitutional support for mentoring.

The use of scaled response formats ensured clarity, improved response reliability, and enabled statistical trend analysis.

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2. Semi-Structured Interviews

To supplement survey findings, semi-structured interviews and focused discussions were conducted with selected students and faculty mentors. These interviews explored, Personal mentoring experiences, Emotional and interpersonal dimensions of mentoring, Institutional barriers and implementation challenges, Suggestions for strengthening inclusive peer mentoring models and the qualitative component provided interpretative depth and helped validate survey patterns.

4.4 Data Collection Procedure

Data collection was conducted through both online and offline modes. Survey links were circulated digitally among students and faculty across selected institutions. Participation was voluntary. Qualitative discussions were conducted in person in an academic setting, allowing participants to express experiences freely. The data collection phase was completed within a defined academic term to ensure consistency in responses.

4.5 Data Analysis Techniques

Quantitative data were analysed using **descriptive statistical methods**, primarily percentage distribution and comparative trend analysis between faculty and student responses. Key performance indicators such as perceived academic improvement (69.6% faculty agreement), emotional well-being impact (92.6% student agreement), and inclusivity perception (73.9% faculty confirmation) were derived from survey responses. Qualitative responses were analysed using **thematic analysis**, where recurring themes such as emotional safety, inclusivity gaps, structured mentoring needs, and time constraints were identified and categorized. The integration of statistical findings with thematic insights allowed triangulation of results, enhancing analytical accuracy and credibility.

4.6 Ethical Considerations

The study adhered to standard academic ethical guidelines. Participation was voluntary, and respondents provided informed consent prior to completing the survey. Anonymity was maintained by avoiding collection of personally identifiable information. All responses were kept confidential and used solely for academic research purposes. Care was taken to ensure sensitivity while addressing topics related to marginalized identities and emotional well-being.

4.7 Insights from the Faculty Survey Analysis:

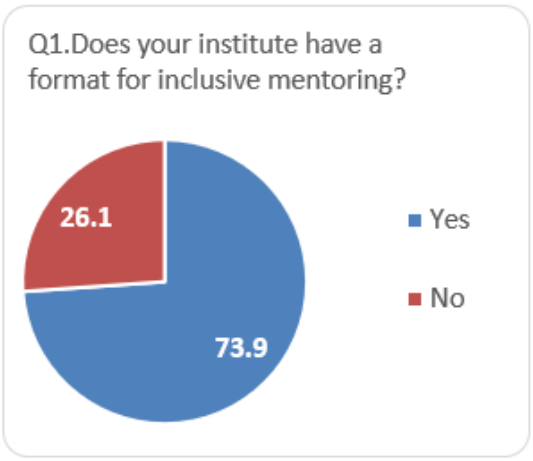


Figure 1: *Format for Inclusive Mentoring*

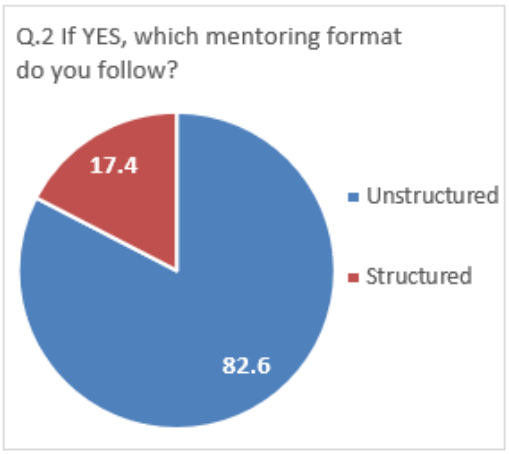


Figure 2: *Type of Inclusive Mentoring*

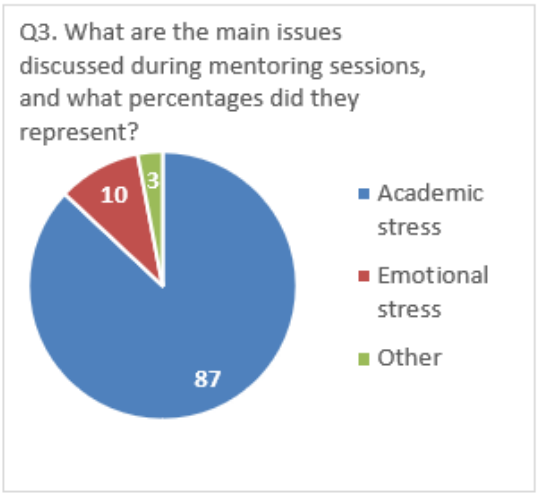


Figure 3: *Issues discussed in mentoring*

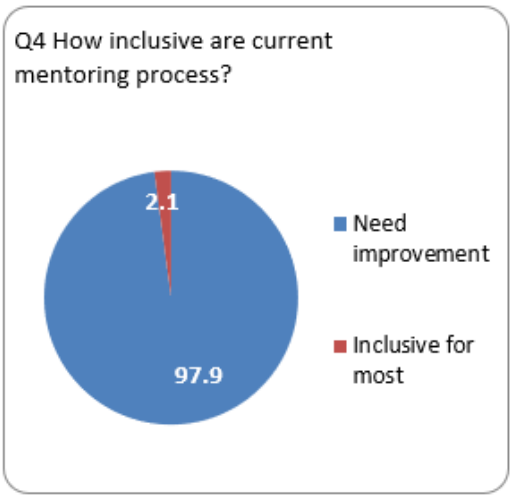


Figure 4: *Current Mentoring Practices*

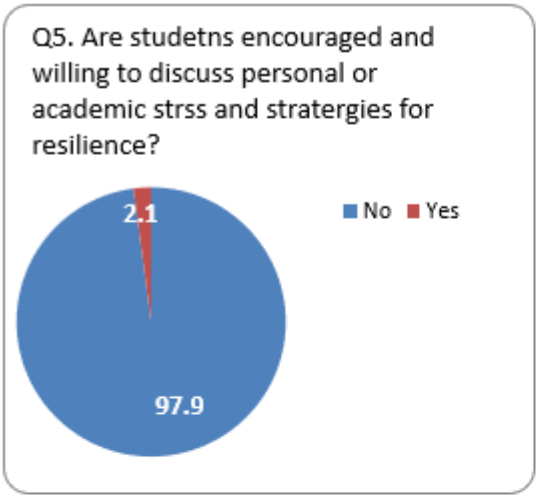


Figure 5: *Willingness to Discuss Academic and Emotional Stress*

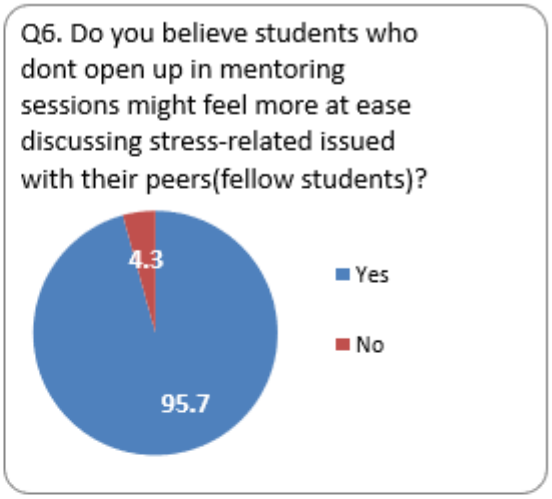


Figure 6: *Challenges faced by students in sessions*

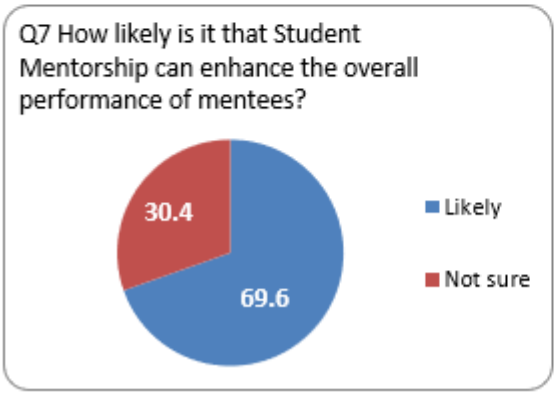


Figure 6: *Need of Student Mentorship*

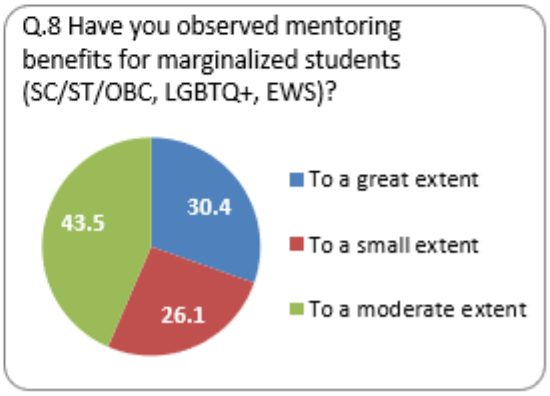


Figure 7: *Mentoring for marginalized students*

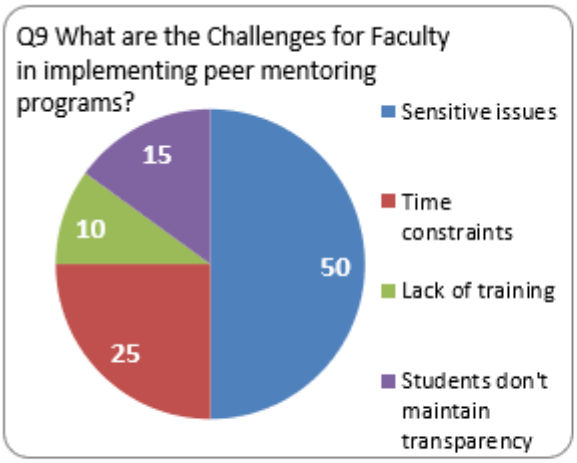


Figure 8: *Challenges for faculty while implementation*

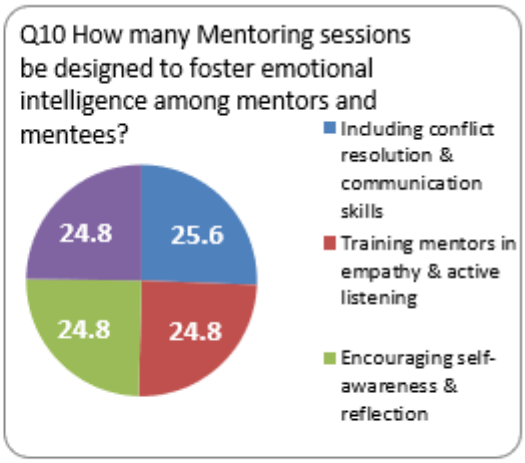


Figure 9: *Designing of Mentoring sessions*

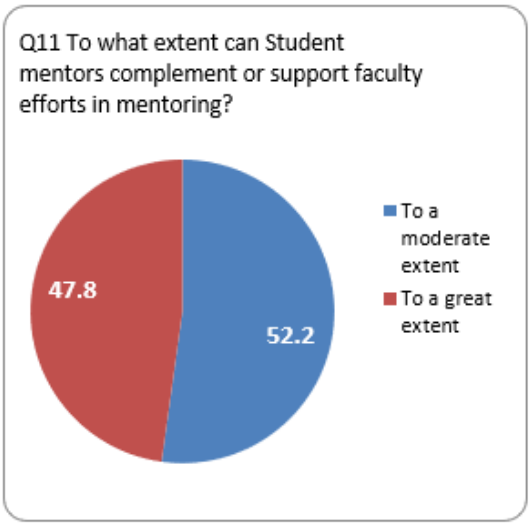


Figure 10: *Student Mentoring complementing faculty mentoring*

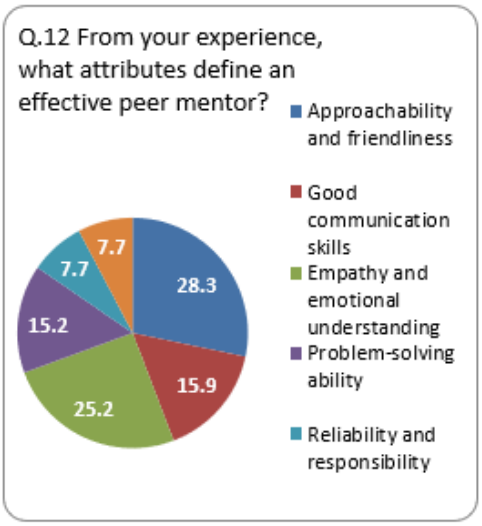


Figure 11: *Effective peer mentoring*

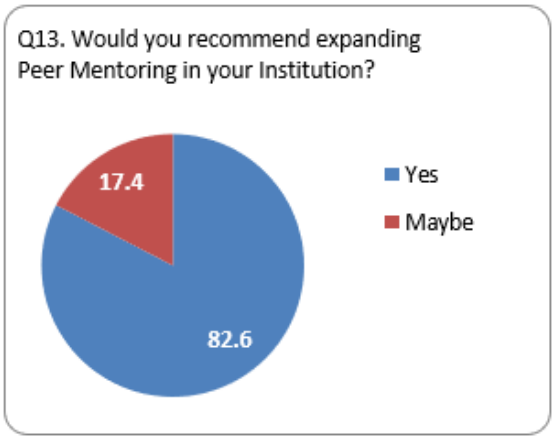


Figure 12: *Expansion of Peer Mentoring*

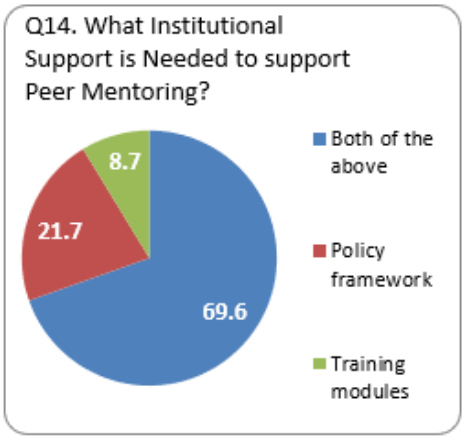


Figure 13: *Institutional Support Required for Peer Mentoring*

Table 1. Summary of Key Findings (Faculty Perspective)

Aspect	Key Finding	Implication
Structured Mentoring	Only 17.4% follow a structured mentoring format	Structured mentoring is very limited — institutions need to develop formalized mentoring systems to ensure consistency and equal access.
Peer Mentoring Support	82.6% recommend expansion	Strong advocacy for student involvement.
Challenges	50% Identified time limitations.	Student-centered peer mentoring fosters openness, allowing mentees to share sensitive concerns with peers, who can then channel key insights to faculty while maintaining confidentiality.
Inclusivity Framework	73.9% have existing models	Requires better consistency and evaluation.
Emotional Focus	87% discussions focused on academic stress	Students may prefer discussing academic stress with faculty but may feel more comfortable sharing emotional concerns with peer mentors.

Source: (https://forms.gle/958AduzrMKsCx7wc6)

4.7 Insights from the Student Survey Analysis:

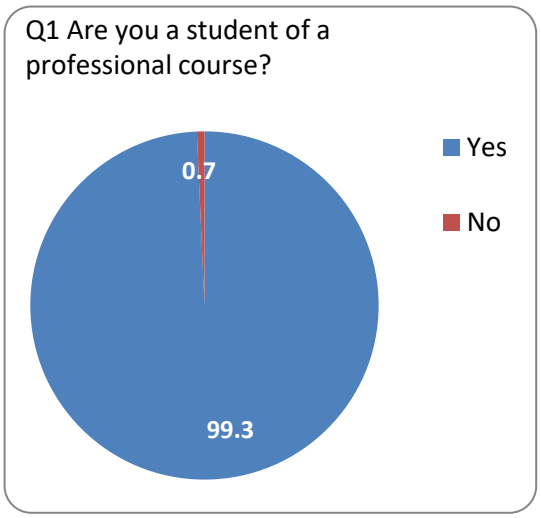
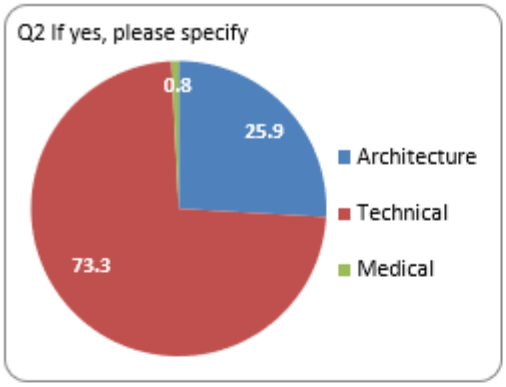


Figure 14: *Type of Profession*



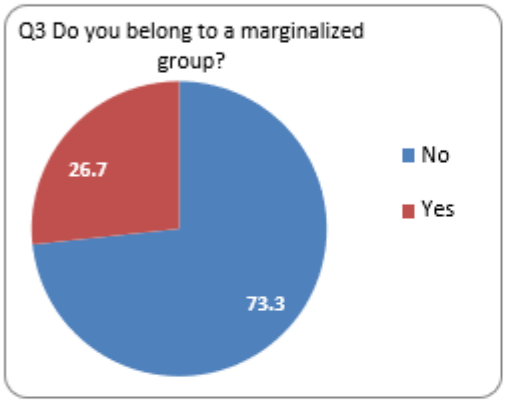


Figure 15: *Belonging to any marginalized group*

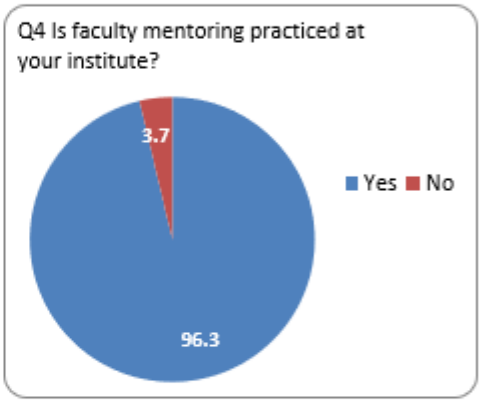


Figure 16: *Practice of Faculty mentoring*



Figure 17: *Practise of Student mentoring*

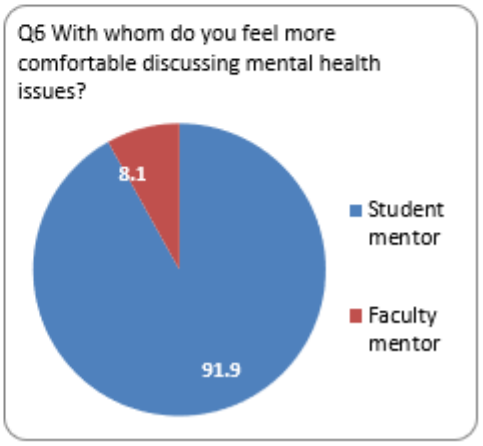


Figure 18: *Comfort to share while discussing issues*

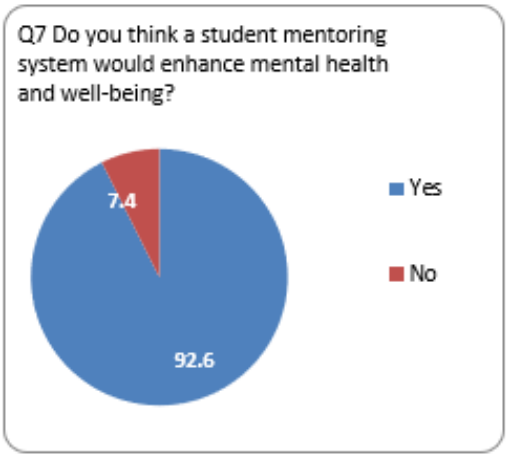


Figure 19: *Effects of student mentoring*

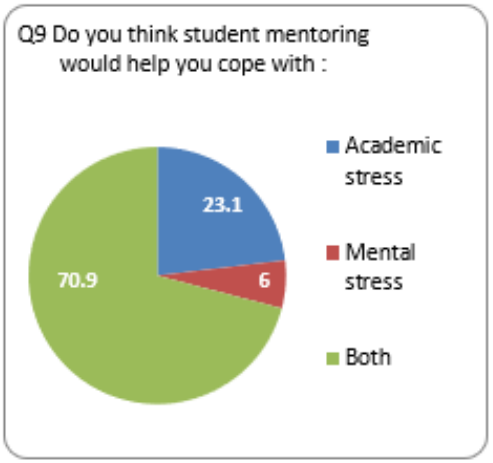


Figure 20: *Student mentoring affecting mental health*

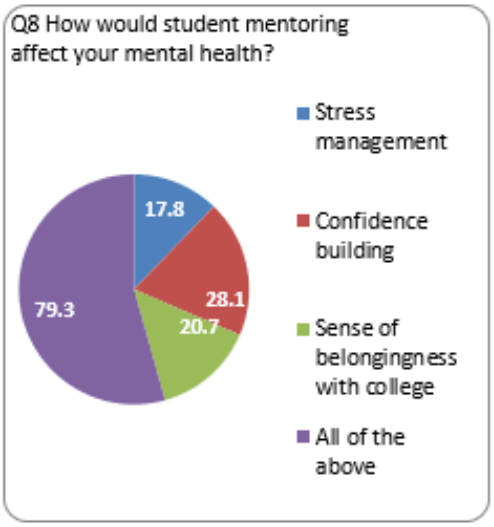


Figure 21: *Coping up with help of student mentoring*

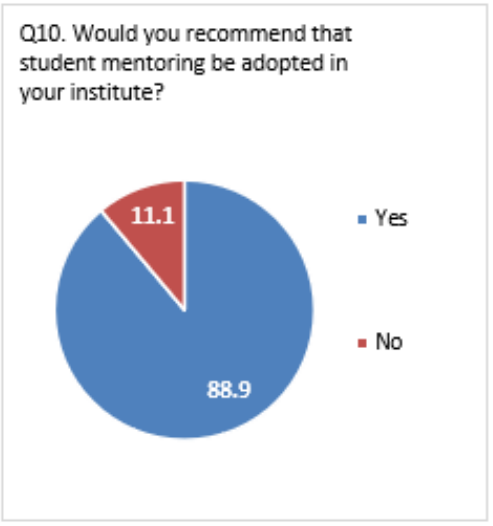


Figure 22: *Opinion on Student mentoring*

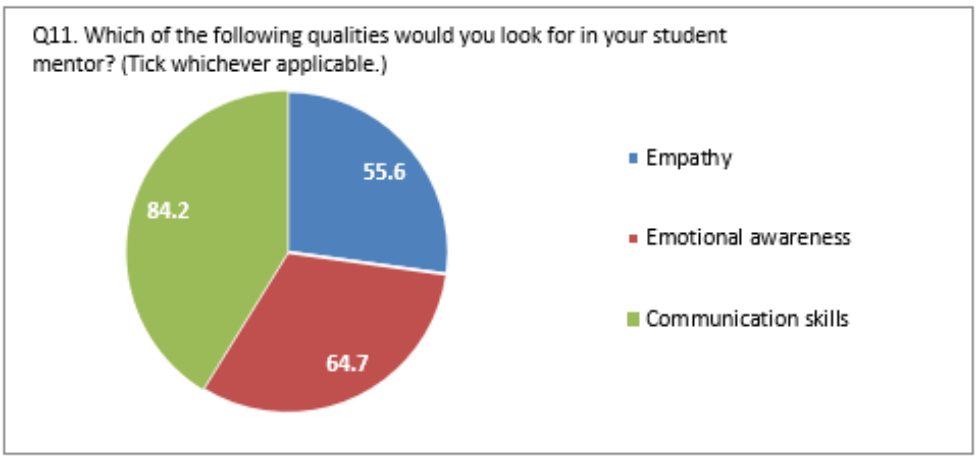


Figure 23: *Qualities of student mentor*

Table 2. Student Survey Highlights

Indicator	**Finding**	**Interpretation**
Faculty Mentoring Availability	96.3%	Mentoring widely practiced.
Peer Mentoring Implementation	91.1%	It highlights the necessity to establish organized initiatives that improve student support and involvement.
Perceived Benefits	92.5% agree	Mentoring enhances mental health and confidence.
Support for Expansion	88.9% recommend it	Strong student endorsement.
Marginalized Representation	26.7%	Reflects need for inclusive frameworks.

Source: (https://forms.gle/SYF3bGF587Hh5u7S8)

Table 3. Impact Summary – Peer Mentoring Outcomes

Parameter	**% Improvement/Support**	**Source**
Academic Performance	69.6% faculty agree	Faculty survey
Emotional Well-being	92.6% students agree	Student survey
Mental Health	79.3% students agree	Student survey
Inclusivity Perception	73.9% faculty confirm but unstructured	Faculty survey

5. Developing a Student Mentoring System

A structured mentoring system is essential to strengthen academic progress, emotional health, and inclusivity in higher education. Although 73.9% faculty and 96.3% students confirm that formal mentoring frameworks exist in many Maharashtra institutions, gaps remain in training, uniform implementation and inclusive execution. Over 92.6% of students believe mentoring supports mental health and well-being, proving its value as a holistic support mechanism. A mentoring system bridges institutional support with individual student needs, providing

academic guidance, emotional encouragement, and peer-based problem solving. When aligned with empathy, emotional intelligence, and UDL principles, mentoring helps students overcome challenges and succeed in diverse learning environments.

5.1 Role of Teachers and Administrators in Facilitating Programs

Teachers and administrators ensure sustainability, quality, and accountability in mentoring. As 69.6% faculty indicate, structured mentoring works best when supported by institutional policies and training. Their responsibilities include defining mentor-mentee guidelines, offering training in communication, inclusivity, and emotional intelligence, and performing continuous evaluation to improve outcomes. This turns mentoring into an institutional practice aligned with NEP-2020 and inclusive education goals.

5.2 Empowering Students to Become Mentors

Over 89% of students recommend expanding peer mentoring, showing strong willingness for student-led initiatives. Empowering students builds leadership, empathy, collaborative learning, and emotional resilience — with 66% linking mentoring to improved confidence, stress management, and belongingness.

- ***Selection Criteria***

1. **Competence and Expertise** – Choose mentors who demonstrate academic excellence, empathy, and interpersonal skills.
2. **Commitment** – Prioritize mentors with a genuine interest in guiding others.
3. **Ethical Standards** – Ensure mentors adhere to confidentiality and institutional values.

- ***Training Programs***

1. **Skill Development** – Include active listening, constructive feedback, and cultural sensitivity training.
2. **Role Clarity** – Define mentor responsibilities and ethical boundaries.
3. **Peer Learning** – Facilitate mentor circles for shared reflection and best practice exchange.

- ***Ongoing Support***

1. **Mentoring Networks** – Establish mentor communities for peer collaboration and emotional support.
2. **Supervision and Feedback** – Implement periodic evaluations to track mentor growth.
3. **Recognition** – Reward mentors' contributions through certificates or credits to sustain motivation.

5.3 Designing Mentorship Activities

For mentoring activities to be successful, academic and emotional development must be integrated. According to polls of faculty and students, the two primary subjects discussed in mentoring sessions are academic stress (87.0%) and students' capacity to handle emotional

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well-being (70.9%). Therefore, the development of emotional intelligence and knowledge exchange should be equally prioritized in the design of activities.

5.3.1 Emotional Quotient (EQ) Development

1. **Emotional Intelligence Training** – Develop mentees' empathy and self-awareness through guided discussions.
2. **Reflective Practices** – Encourage journaling or peer reflection exercises to promote self-understanding.
3. **Feedback Loops** – Create safe, two-way feedback channels for continuous improvement.

5.3.2 Inclusivity and Peer Support

1. **Diversity Awareness** – Integrate sessions on cultural sensitivity and social equity, especially for marginalized groups (26.9% of respondents).
2. **Group Activities** – Promote collaborative learning through workshops and team projects.
3. **Inclusive Practices** – Incorporate UDL principles to cater to varied learning preferences and accessibility needs.

6. Comprehensive Strategies for Enhancing Student Support Systems in Higher Education

Based on the analysis, the following evidence-based strategies can strengthen mentoring as a core institutional support system. Both faculty and student data highlight emotional intelligence as a critical success factor in mentoring. The table outlines key parameters for establishing a structured peer mentoring framework, detailing implementation strategies and their expected outcomes. It highlights essential aspects too.

Table No. 1: Integrated Parameters & Strategies for Structured Peer Mentoring Framework

Parameter / Focus Area	Strategy / Implementation Details	Expected Outcome
Mentor & Mentee Selection	Clear eligibility criteria (academic performance, leadership, discipline record). Ensure diversity across gender, discipline, background	Fair selection, inclusive participation, equitable access to mentorship.
Training & Capacity Building (including Emotional Intelligence)	Orientation on ethics, confidentiality, communication; modules on listening, feedback, cultural sensitivity; EI workshops on empathy, resilience & emotional regulation.	Well-prepared mentors, improved mentor–mentee relationships, holistic student growth.

Inclusivity & Access (including LGBTQ+ Support)	Accessibility audits, digital inclusion workshops; UDL-based flexible activities & multiple communication modes; LGBTQ+ ally ship training & safe-space mentoring through gender cell.	Strengthened belonging, reduced discrimination, and psychological safety for diverse groups.
Mentoring Structure & Scheduling	Semester/year-based duration; bi-weekly/monthly meetings; logs & progress reports; mix of group + one-to-one models.	Consistent engagement and effective mentoring relationships.
Monitoring, Documentation & Feedback	Mentor logs, summaries, mentee progress sheets; faculty coordinator review; mid-term + end-term evaluation.	Continuous quality monitoring and adaptive mentoring improvements.
Evaluation & Institutional Quality Assurance	Outcome tracking (GPA, retention, satisfaction); annual program impact review aligned with institutional/NEP quality standards.	Measurable success and institutional accountability.
Recognition & Incentives	Certificates, credits, best mentor awards; leadership pathways for senior mentors.	Motivation, sustained participation, student leadership development.

7. Conclusion

The findings affirm that mentoring significantly enhances academic achievement, mental health, and inclusivity within higher education. With **over 89% of students** endorsing its expansion and **82% of faculty** supporting its institutionalization, peer mentoring emerges as a cornerstone for educational equity.

By integrating **UDL**, **emotional intelligence**, and **inclusive excellence** into mentoring systems, HEIs can transform traditional support models into dynamic, student-centred ecosystems. Strengthened by evidence-based practices and ongoing assessment, these frameworks can attempt to ensure that all learners—regardless of identity, background, or ability—thrive academically and emotionally.

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Transitional In-Between Spaces as Contemporary Third Places: Facilitating Equity and Social Wellbeing.

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Abstract: In pursuit of improving the efficiency of cities and proposing rational schemes, the richness and complexity of the historic city were often lost, leaving contemporary life deprived of spaces suitable for everyday interaction. The organic character of older urban environments, with intersecting streets and incidental meeting points, gave way to rigid planning models that often overlooked the human scale. According to Ray Oldenburg in his book *The Great Good Place*, "Third Place" is defines as an informal gathering space away from home (first place) and work (second place). Such spaces are neutral, accessible, and foster a sense of community through spontaneous interaction. However, in today's rapidly densifying Indian cities, emphasis lies on building infrastructure and housing; traditional third places such as plazas and town squares are either shrinking or transforming. What emerges instead are "third spaces"- usually transitional in between spaces that are adaptable based on time, function and density, while retaining the core quality and characteristic of a Third Place. Through a combination of literature review, spatial analysis, and a user perception survey, this paper examines how transitional in-between spaces at different scales and levels of programming can function as contemporary "Third Places" fostering equity, inclusion, and social well-being in densifying Indian cities.

Keywords: Third Place; Transitional in-between spaces; Social well-being; Informal interaction

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1. Introduction

According to Ray Oldenburg's theory, "Third Place" refers to the social surroundings that are separate from the two usual environments of home (first place) and the workspace (second place). These third spaces are informal, welcoming spaces where people gather, socialize, build connections, and foster a sense of community (Oldenburg 1989). Thus, they are defined not by their physical form but more by the qualities of interaction they enable or facilitate. It is a place where social and monetary status become less significant; it essentially acts as a leveler. Conversation is the central activity of a Third Place, which is supported by easy access. They are set in an environment marked by informality and encouraging spontaneity.

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1.1 Decline of Traditional Third Place

Earlier public plazas and town squares/centers used to facilitate these interactions. However, due to urban planning guidelines, rising population density and the greater need for housing and transport, these types of public spaces have diminished or, in some cases, disappeared entirely. While URDPFI Guidelines recommend 10-12 sqm per person, actual per-capita public open space in many Indian cities is significantly lower, for example, Mumbai (~1.28 sqm), Bengaluru (~2 sqm), and Chennai (~0.81 sqm) per person. (CEPT University City Studio, as cited in *The Times of India*, 2025).

Indian streets have prioritized motorized traffic, allocating limited space for pedestrians and other non-motorized users in design (ITDP India, 2021). These urban dynamics/ planning will lead to cities that lack a sense of community and do not have an adequate mix of public, private and semi-private spaces.

"In pursuit of improving the efficiency of cities and proposing a rational scheme that responded to the advances of the Industrial Revolution, the richness and complexity of the historic city was completely lost, and cities were deprived of spaces suitable for everyday life." (Santos-García, A., & Aseguinolaza Braga, I. 2025, p.02)

1.2 Controversies related to Third Place

Old-style community-driven places once built trust and acted as safety nests for the neighborhood but were then increasingly replaced by chain cafes and malls. These market driven venues have turned community relationships into ones that revolve around consumption and consumerism; a process often referred to as the “commercialization of friendship” (Silver, A. 1990). Franchised cafes and brands have expanded, pushing out the local users, creating a homogenized experience where distinct communities and their identities fade (Wexler, M. N., & Oberlander, J., 2017).

In Indian context, this shift is seen in the gradual replacement of *Chai Tapris*, everyday social nodes, with franchised cafes where interaction and access are shaped more by commercial expectations than by familiarity and routine.

Online spaces such as social media platforms, multiplayer games and digital forums are often described as the new form of third place, i.e., Digital Third Place. These digital spaces are operated within ecosystems where user attention, data and behavior are commodified and profited from. This commercial logic clashes with the original concept of Third Place, the spirit of open, community-oriented interactions. Though they provide convenience and global reach, the absence of physical presence, shared atmosphere, and shared contact weakens the sense of belonging and community that traditional, physical third places fostered.

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2. Adaptation in the Contemporary Urban Context

Thus, to suit the current urban context, these spaces need to be adapted into transitional spaces and in-between spaces. In contrast to Third Places, which have a specific function assigned to them (cafes, parks, town halls), these in-between places are unprogrammed/semi-programmed spaces which have the potential to adapt. These spaces change based on function, density, locality, and human intervention. Their emergence is closely linked to visibility, perceived safety due to continuous activity, and basic user comfort.

To understand these in-between spaces, their spatial characteristics and what enables them to function as successful third spaces, three cases were studied. Manek Chowk in Ahmedabad, Kalakaar Katta at FC Road, Pune, and the redesigned pavement at JM Road, following the smart city initiative.

While each function in different contexts and based on diversity in scale, they have certain similar characteristics that facilitate informal interaction and adaptability.

2.1. Manek Chowk, Ahmedabad

Manek Chowk is one of the liveliest markets in Ahmedabad, continually transforming throughout the day. It begins as cattle grazing ground during the morning, a jewellery market by day and transforms into a vibrant food hub during the evening (Shukla, A., & Navratra, N. D. 2017). Manek Chowk is an apt example of how public spaces are adapted due to functions and human intervention. Spatial characteristics like central location, easy access, edges and enclosure, and flexible open core allow the space to function as a successful third space.

2.1.1 Edges and Enclosure

The chowk is surrounded by continuous building edges, temples, havelis, shops and jewellery stores that form a strong sense of enclosure while still being porous and define the spatial boundary.

2.1.2 Flexible Open Core

Manek Chowk’s adaptability lies in its central open core. There are no permanent fixtures, thus allowing the space to take whatever form necessary based on time, function, and density.

2.1.3 Transformation

The Chowk's ability to shift functions and shape interactions throughout the day highlights its dynamic nature. Morning, afternoon, and evening each bring in diverse groups and different social inteactions.

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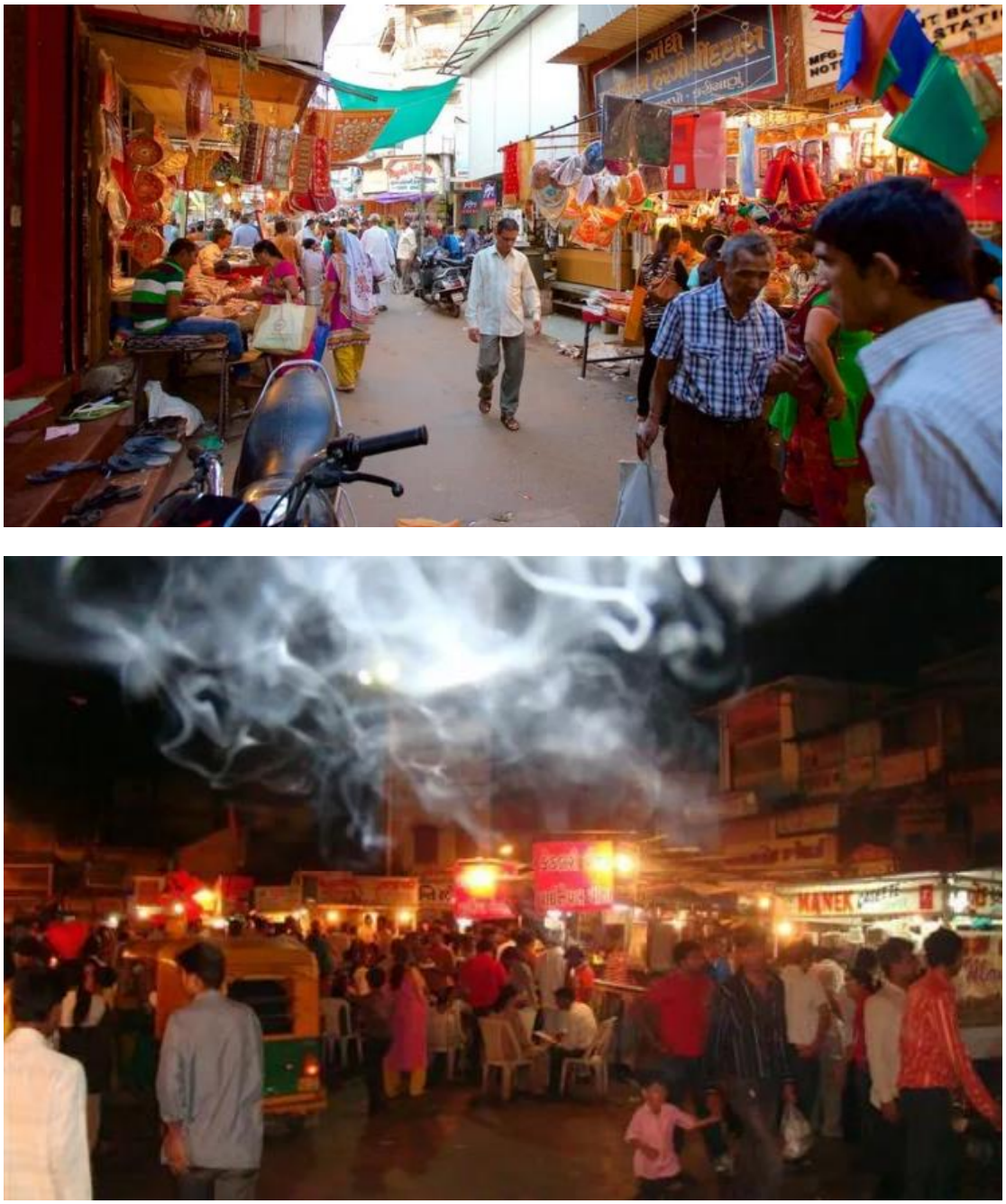


Figure 1. Day and night transformation of Manek Chowk highlights its adaptive public use. Image sources: Expedia (n.d.), Pinterest (n.d.).

While Manek Chowk in Ahmedabad functions as an adaptable public square with varying functions and defined built edges, Kalakaar Katta at FC Road, Pune transitions from a spillover space into an organically grown public space. The shift from a defined, bound central open space to the peripheral street edge zone highlights the adaptability of a third space across different spatial forms and scales.

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2.2 Kalakaar Katta at Fergusson College Road, Pune

Kalakaar katta acts as an informal social node for students and artists, facilitating spontaneous interactions and performances. The Kalakaar Katta outside Goodluck cafe was originally a spillover space that turned into a semi-programmed interaction space, i.e., it has minimal physical interventions.

2.2.1 Seating and Shade

Seating encourages people to linger, enhancing interactions and community building. Seating around the trees, low steps, benches, and stool stumps have been provided. Tree canopies provide shade and create a comfortable experience, thus allowing people to stay longer. The trees also act as a buffer against street noise and break up the hardscape around.

2.2.2 Accessibility and Proximity

Kalakaar Katta is situated along Fergusson College Road, accessible by both vehicular and pedestrian movement. Its proximity to educational institutes, small shops and food stops makes it a prime interaction spot for students and young adults. Its convenient location allows spontaneous interaction, creating a vibrant, informal third space.



Figure 2. Kalakaar Katta on FC Road, Pune (photo credit: Anand Patil / Achal DS, via What's Hot Pune

While Kalakaar Katta emerged through everyday use and informal gatherings, the JM Road pavement is a result of intentional urban design through the Smart City Initiative. The transition from community-driven edge to formally designed public space reflects how planned spaces can still reflect the spirit of a third place and can nurture spontaneity and interaction when designed with human behaviour and patterns in mind.

2.3 JM Road Pavement

The redesign of Jangali Maharaj Road (JM Road) as a part of Pune's Smart City initiative transformed the pavements into a rich social space for interaction and commute. The footpaths

were widened, green buffers were added to segregate pedestrians and cycle paths, and seating was added. (Naushad, 2017)

2.3.1 Nodes and Pause points.

Strategically placed seating and pergolas allowed users to pause, interact, and experience the space. These points break the linearity of the long footpaths and create social nodes. Shade from the tree canopies also helps in creating a comfortable experience for the users.

2.3.2 Proximity and Accessibility

JM Road is centrally located and in proximity to educational institutions, commercial hubs, and cultural landmarks. The wide, shaded footpaths along the busy street are easily accessible by public transport like buses, metros, and pedestrian routes, making the pavement a convenient and inviting public space for everyday use.



Figure 3. *JM Road streetscape, Pune (image via FuturArc / Oasis)*

3. User Perception of Everyday Third Spaces

To verify the insights from the case studies, a survey was conducted to identify the spatial characteristics that people value in the informal spaces where they spend their time. The survey focused on user perceptions of space and patterns; demographic details such as age and gender were not recorded.

Responders consistently pointed to places to sit, shade, safety and visibility, food stalls nearby, informality and proximity to colleges or residential areas as the most important characteristics. Seating and shade emerged as the most chosen options, followed by an informal atmosphere where people can linger without the need to buy anything.

In combination with the insights from the case studies, these findings from the survey allow us to compile a set of spatial characteristics that facilitate the success of a “Third Space” and actively support interaction and community building. These characteristics can further be

supported and explained through Christopher Alexander's Pattern Language, where he speaks about human centric, interactive public spaces.

3.1 Survey Findings

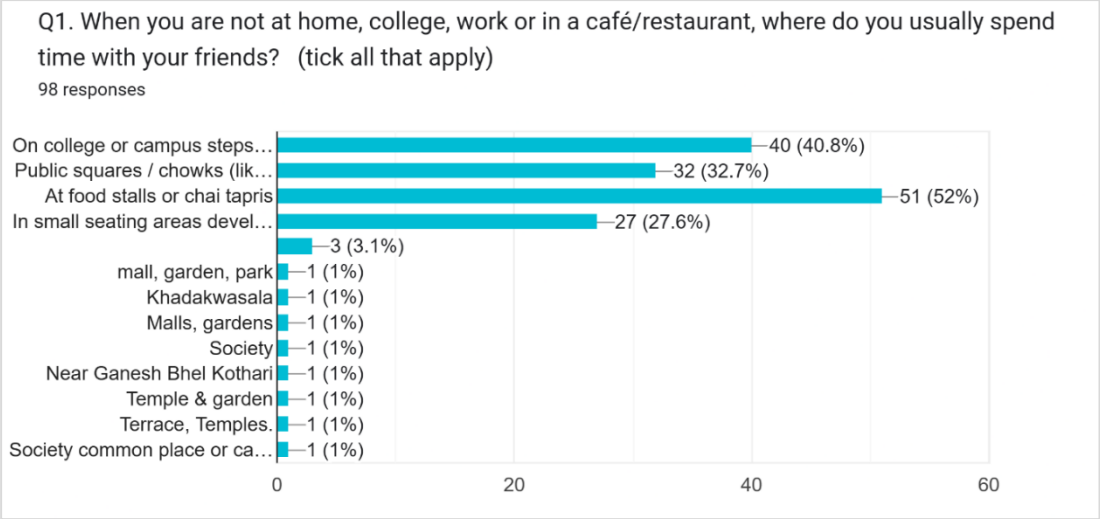


Figure 4. Responses to Q1: Usual informal places where people spend time with friends. (**Source**: Author's primary survey, 2025; n = 98)

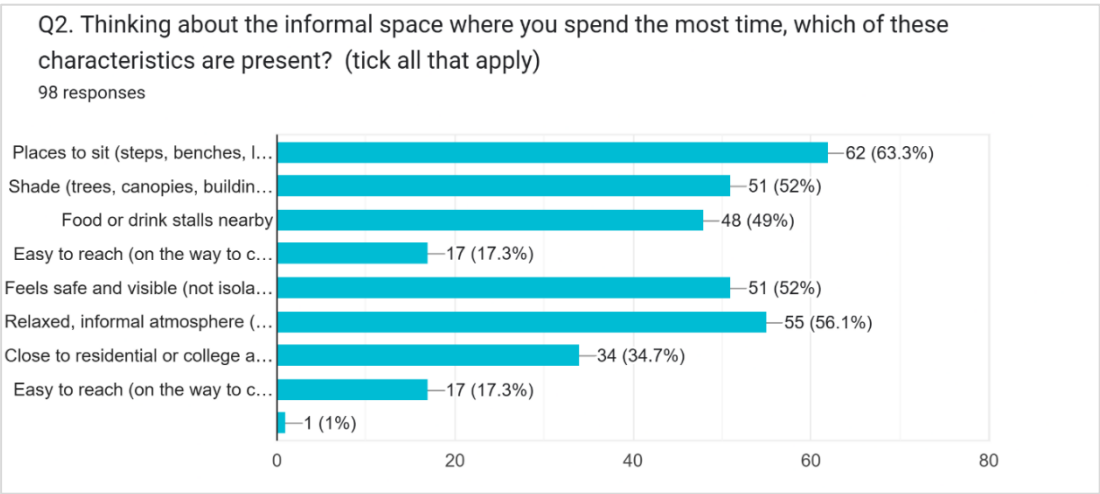


Figure 5.: Responses to Q2: Spatial characteristics present in frequently used informal spaces. (**Source**: Author's primary survey, 2025; n = 98)

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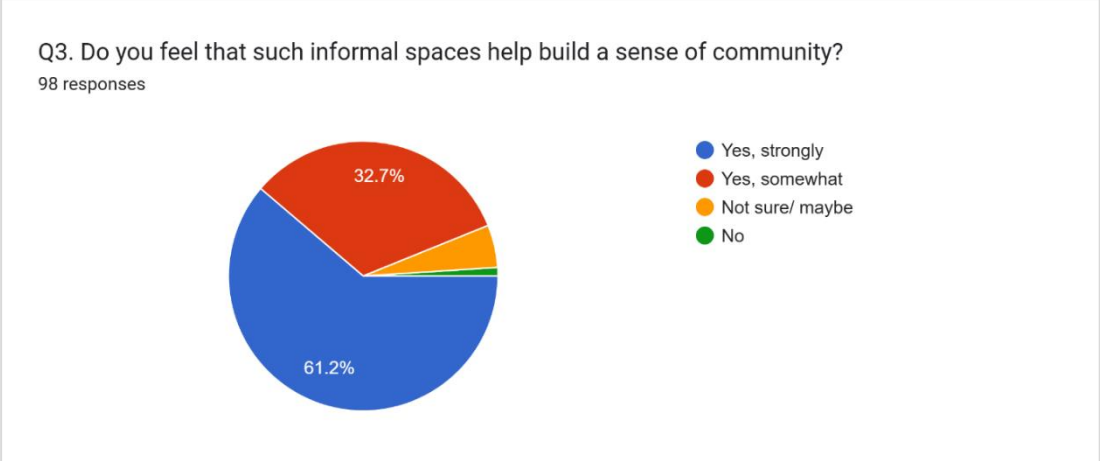


Figure 6. Responses to Q3: Perceived contribution of informal spaces in building community. (**Source:** Author's primary survey, 2025; n = 98)

3.2. Spatial Characteristics for Third Places: Case Study Comparison

Table 1. Comparison of Spatial Characteristics in Case Studies with Reference to Christopher Alexander's Pattern Language

Spatial Characteristic	**Manek Chowk**	**Kalakaar Katta**	**JM Road Pavement**	**Christopher Alexander – Pattern Language**
Seating *(steps, benches, low walls, plinths)*				*Pattern 241: Seat Spots* *Pattern 125: Stair Seats*
Shade *(trees, canopies, building edges)*				*Pattern 171: Tree Places*
Food & Drink Stalls Nearby				*Pattern 87: Individually Owned Shops / Pattern 93: Food Stands*
Accessibility & Proximity *(on routes near colleges, markets, residences)*				*Pattern 120: Paths and Goals Pattern 30: Activity Nodes*

Safety & Visibility *(public view, not isolated)*				*Pattern97: Shielded Parking (visibility & social safety)*
Informality *(relaxed atmosphere, no pressure to consume)*				*Pattern 69: Public Outdoor Room* *Pattern 33: Night Life*

Somewhat Applicable Majorly Applicable

4. Conclusion

As Indian cities grow denser and traditional third places gradually disappear, the idea of the third place evolves into a *third space*, a more fluid, adaptable and inclusive urban realm that supports equitable access to shared environment. These contemporary "third spaces" integrate elements such as social seating, shade, an informal and relaxed atmosphere, and pause points, identified through the *combined analysis of the case studies and user perception survey*, that foster inclusivity, bring the community together, and restore social vibrancy.

Such in-between spaces are not leftovers; they are pockets that actively facilitate interaction and community building. The spatial characteristics derived from the case studies and the survey findings demonstrate how design can foster adaptability, informality, and shared use while encouraging a sense of belonging across diverse user groups. When consciously integrated, these spaces help create a vibrant, inclusive urban environment, making the interaction more enriching and building communal bonds.

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Study of Pedestrian Infrastructure at Gandhi Bazaar, Bengaluru: A Focus on Safety, Comfort, and Pleasure

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Abstract: Urban streets play a crucial role in fostering social interaction, economic activity, and sustainable mobility. The Gandhi Bazaar in Basavanagudi, Bengaluru, represents one of the city's oldest and most vibrant commercial and cultural corridors, attracting large volumes of pedestrians throughout the day. This study evaluates the pedestrian infrastructure of Gandhi Bazaar with respect to three critical dimensions: safety, comfort, and pleasure. Using data from the Directorate of Urban Land Transport's (DULT) Pedestrianization of Gandhi Bazaar Study, supplemented by field observations and literature review, the research analyzes the existing footpath conditions, pedestrian behavior, and the effects of the rejuvenation and pedestrianization efforts. The findings highlight the street's unique spatial and cultural dynamics where commercial vitality coexists with pedestrian and vehicular conflict. The study concludes that while the rejuvenation improved physical infrastructure through widened sidewalks, improved lighting, and designated hawking zones challenges remain in ensuring user safety, maintaining comfort under encroachment pressures, and preserving the pleasure of the walking experience. Recommendations emphasize inclusive design, conflict management, and continuous engagement between authorities, hawkers, and the community to sustain Gandhi Bazaar as a model pedestrian street balancing commerce, culture, and urban livability.

Keywords: Pedestrianization; safety; comfort; pleasure; Liveability; urban design.

1. Introduction

Streets constitute fundamental elements of the urban fabric, operating not only as circulation corridors but also as spaces where economic exchange, cultural practice, and social interaction converge. Streets with active frontages and continuous pedestrian presence contribute significantly to urban vitality and public safety (Jacobs, 1961; Gehl, 2010). Contemporary urban design scholarship increasingly emphasizes pedestrian-oriented streets as critical to fostering inclusive, human-scaled environments. Such streets are evaluated through the interrelated dimensions of safety, comfort, and pleasure, which together shape the quality of the walking experience. Safety concerns the mitigation of vehicular conflict and the clarity of movement systems. Comfort relates to spatial continuity, surface quality, shading, lighting,

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and accessibility. Pleasure arises from sensory richness, active frontages, and opportunities for social engagement within the public realm (Gehl, 2010).

Within this conceptual framework, Gandhi Bazaar in Basavanagudi, Bengaluru, offers a compelling case for examining pedestrianization in a heritage market context. The approximately 300-meter stretch between K.R. Road and D.V. Gundappa Road functions as a dense commercial spine embedded within a predominantly residential precinct. Characterized by traditional retail establishments, religious landmarks, eateries, and informal vendors, the bazaar serves both daily neighborhood needs and city-wide cultural events such as the Kadalekai Parishe. However, increasing vehicular traffic, commercial spillovers, and rising pedestrian volumes have generated spatial conflicts that challenge both mobility and the preservation of cultural identity.



Figure 1. *Location map of the Gandhi Bazaar study area, Basavanagudi, Bengaluru.*
Source: *Adapted by the author using OpenStreetMap base map (OpenStreetMap contributors, n.d.).*

In response, urban authorities-initiated redevelopment measures aimed at widening sidewalks, reorganizing vending activity, and improving lighting and infrastructure. While these interventions strengthened the physical framework of the street, tensions between formal design intent and everyday use persist. This study therefore evaluates Gandhi Bazaar through the lens of safety, comfort, and pleasure to understand how design interventions interact with informal practices in shaping walkability. By situating the analysis within the broader discourse on pedestrianization in Indian cities, the paper contributes to discussions on designing adaptable and culturally responsive urban streets.

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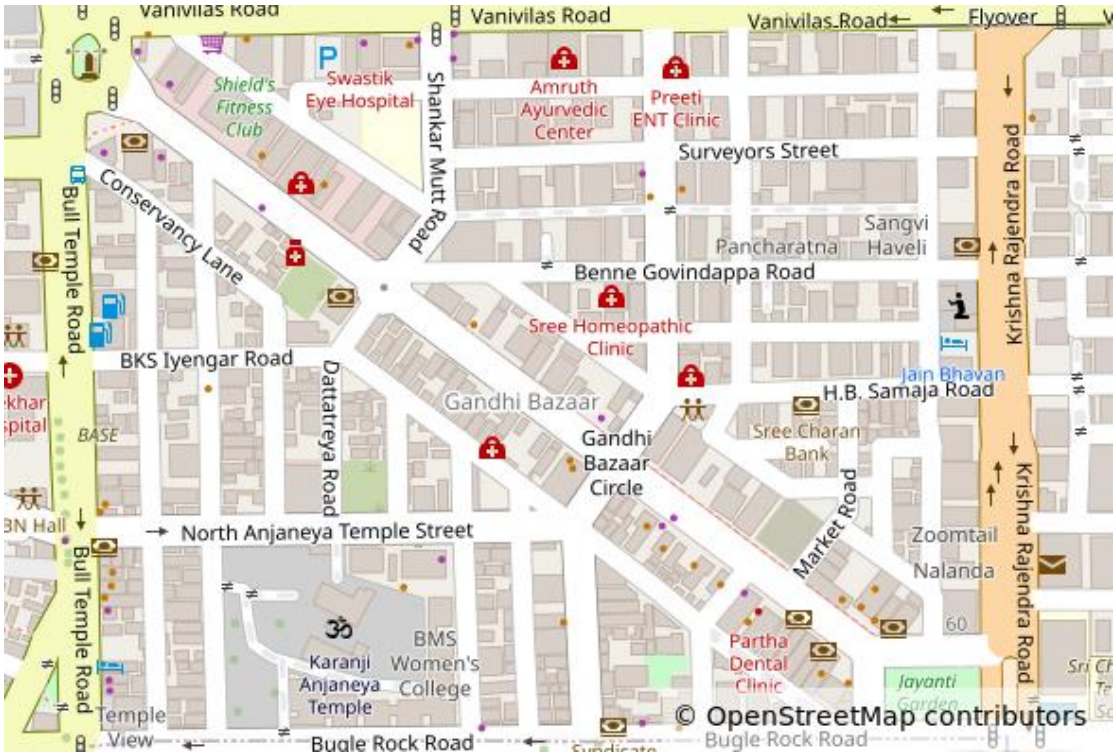


Figure 2. *Detailed location map of the Gandhi Bazaar study area, showing the street network,*
Source: Adapted by the author using OpenStreetMap base map (OpenStreetMap contributors, n.d.).



Figure 3*: Existing street environment of Gandhi Bazaar Soutce- The Hindu 2024*



Figure 4: *Flower vending activity in Gandhi Bazaar.* ***Source-*** *Citizen matters*



Figure 5: *streetscape of Gandhi Bazaar showing pedestrian activity, flower vending, and vehicular circulation.*
Source- *The Hindu 2024*



Figure 6: *Vidyarthi Bhavan Landmark restaurant of Bangalore*
Source *- Indian Express*

2. Literature study:

2.1 Understanding Pedestrian Streets

Pedestrian streets are urban environments designed primarily for foot-based movement, where vehicular access is either restricted or carefully regulated. Unlike conventional roadways that prioritize motorized transport, these streets are structured around human scale and everyday public life. Their objective is not merely to facilitate movement but to create conditions that support safety, accessibility, and social interaction. In such settings, walking becomes both a functional necessity and a meaningful urban experience, fostering economic exchange, cultural expression, and collective presence (Mehta, 2013).

Scholarly discourse emphasizes three interrelated dimensions that define the quality of pedestrian environments: safety, comfort, and pleasure (Gehl, 2010). Safety refers to minimizing conflict between pedestrians and vehicles through traffic calming, clear crossings, and spatial clarity. Comfort encompasses the physical and environmental attributes that enable ease of movement, including continuous pavements, adequate lighting, shade, seating, and barrier-free access. Pleasure extends beyond functionality, arising from sensory engagement, active street edges, architectural diversity, and opportunities for informal social interaction. Effective pedestrian streets integrate these elements into a coherent spatial system that supports both circulation and lingering.

2.2 Pedestrianisation in the Indian Urban Context

Pedestrianisation initiatives in Indian cities represent an effort to reconcile contemporary urban design principles with historically layered street cultures. Interventions in areas such as Chandni Chowk in Delhi, the Charminar precinct in Hyderabad, and Gandhi Bazaar in Bengaluru illustrate varied outcomes in balancing mobility improvement with livelihood preservation. Research indicates that projects incorporating sustained stakeholder

participation and adaptive regulatory mechanisms demonstrate greater resilience and long-term functionality (Mahadevias & Lathia, 2019).

A recurring concern within Indian Pedestrianisation efforts is the divergence between formal design intent and everyday spatial practices. While redesigned streets frequently enhance paving quality, lighting, and visual coherence, their durability depends heavily on maintenance regimes, enforcement capacity, and public acceptance. In the absence of these supporting systems, pedestrian-priority zones often experience incremental encroachment and reduced effectiveness. Consequently, context-sensitive strategies that account for local socio-economic patterns are essential. Rather than replicating Western pedestrian models, Indian streets require hybrid frameworks capable of integrating regulation with informality.



Figure 7: *Chandni Chowk in Delhi*
Source - *The Hindustan Times*



Figure 8: *Charminar precinct in Hyderabad*
Source- *Telangana Today*

3. Study Area – Gandhi Bazaar

Gandhi Bazaar is situated within Basavanagudi in South Bengaluru, a precinct historically recognised as one of the city's cultural anchors. The area emerged after the 1898 plague as part of a planned "model hygienic suburb," laid out over approximately 440 acres with a grid-iron pattern, wide streets, and a balanced allocation of residential, institutional, and open spaces. Its identity is closely tied to prominent religious landmarks such as the Dodda Basava (Bull) Temple and the Gavi Gangadhareshwara Temple, along with institutions like the Ramakrishna Ashram and Shankar Mutt, which continue to reinforce its cultural significance

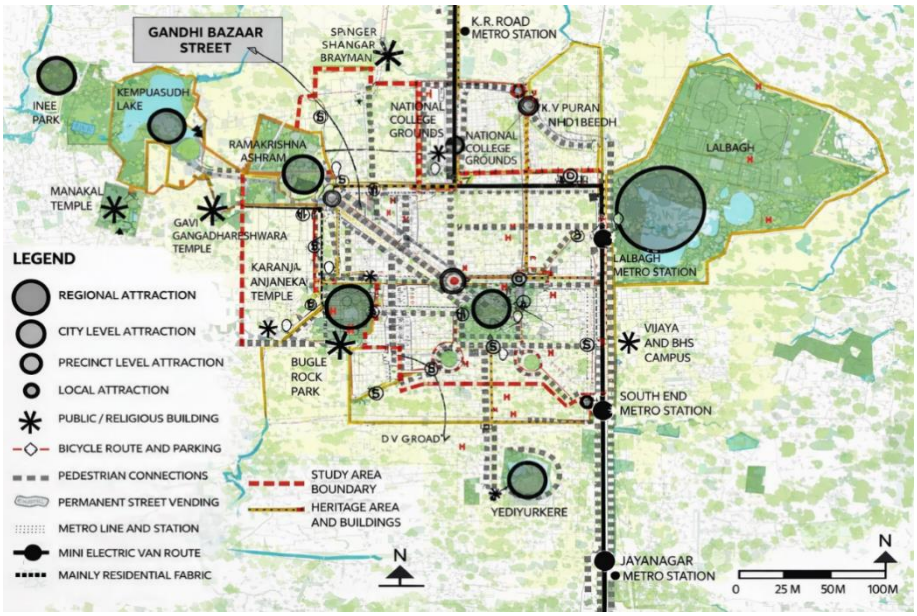


Figure 9: *Spatial context and connectivity of the Gandhi Bazaar study area.*
Source: *DULT redevelopment data*

Within this structured urban fabric, Gandhi Bazaar developed as the primary commercial and social spine. The 300-meter stretch between K.R. Road and D.V. Gundappa Road functions as a dense mixed-use corridor serving surrounding neighbourhoods including NR Colony and VV Puram. The precinct is further supported by green assets such as Lalbagh Botanical Garden and Bugle Rock Park, alongside strong metro connectivity, enhancing accessibility and pedestrian movement.

The bazaar operates from early morning to late evening, with peak activity driven by ritual-based commerce, traditional food shops, and flower markets. Annual events such as the Kadalekai Parishe reinforce its city-wide cultural relevance. However, increasing traffic and commercial intensity have introduced spatial conflicts. Recent redevelopment (2022–2024) has improved infrastructure, yet the area continues to function as a hybrid environment where formal planning and informal practices coexist, shaping its unique pedestrian experience.



Figure 10: *archival photograph of Gandhi bazaar*
Source- *Old Bangalore-Facebook page*



Figure 11 *archival photograph of Gandhi bazaar*
Source- *Deccan Herald*

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3.1 Redesign of Gandhi Bazaar

Core Design Concept

The redevelopment of Gandhi Bazaar aims to transform it into a pedestrian-priority heritage corridor integrating mobility, commerce, culture, and landscape. The design rebalances pedestrian and vehicular movement, promoting walkability while allowing controlled access. Informal activities are organized within designated zones rather than removed. The street is envisioned as a continuous civic space supporting social interaction, ritual, and everyday exchange, with heritage, ecology, and movement forming an integrated urban framework.



Figure 12: *Stakeholder mapping of the Gandhi Bazaar precinct.*
Source- *AMRUT Gandhi Bazaar DPR*



Figure 13: *Redevelopment works at Gandhi Bazaar*
Source: *The Hindu.*



Figure 14: *Installation of vendor infrastructure during the Gandhi Bazaar redevelopment*
Source: *The Hindu.*

Linear Stretch-Based Planning Approach

The master plan structures Gandhi Bazaar into three connected segments, each responding to its context. The first stretch (Ramakrishna Ashram Circle to Vysar Mutt Junction) focuses on gateway identity and traffic calming. The second stretch forms the main commercial core with

high pedestrian activity and vending. The third stretch (towards Tagore Park) acts as a transition zone, encouraging leisure and spill-out along the park edge.

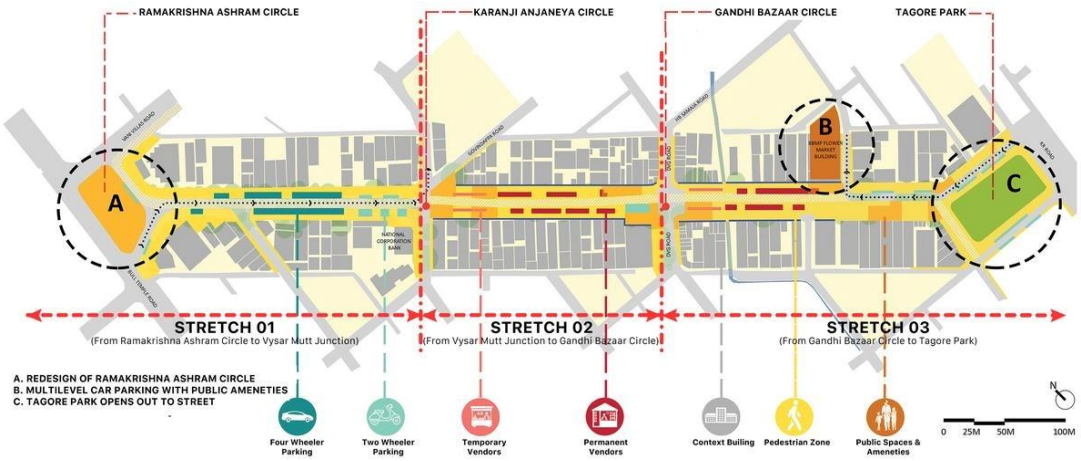


Figure 15: *Proposed master plan for the redevelopment of Gandhi Bazaar.*
Source: The Hindu

The redesigned cross-section prioritizes pedestrians while allowing controlled vehicular movement. Continuous footpaths on both sides are supported by designated vending zones to reduce encroachment. Tree-lined buffers improve microclimate and visual quality, while a narrower carriageway accommodates slow traffic. Integrated seating, lighting, and shelters enhance the street's function as an active public space.

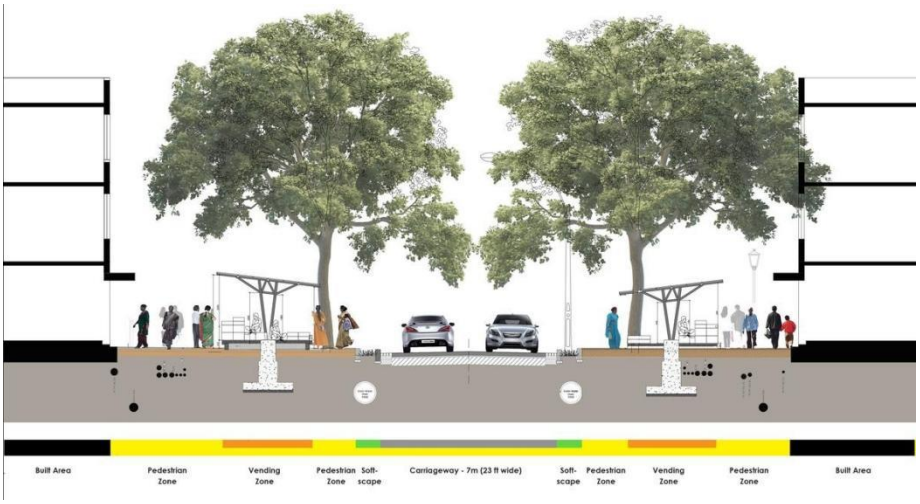


Figure 16: *Proposed Section for the redevelopment of Gandhi Bazaar.*
Image Source: *The Hindu*

4. Methodology

4.1 Aim

This study investigates the functioning of Gandhi Bazaar as a pedestrian-oriented street following recent redevelopment interventions. It evaluates how the redesigned infrastructure supports everyday walking practices within a traditional market environment. The analysis focuses on pedestrian experience through the interrelated dimensions of safety, comfort, and pleasure. In addition, the research examines the relationship between planned design intentions and actual patterns of use, particularly in the context of informal economic activities, high pedestrian density, and culturally embedded practices characteristic of Indian bazaars.

To achieve this objective, a multi-method framework was adopted to assess the interaction between spatial configuration, infrastructural quality, and user behaviour. The methodology integrates site observation, pedestrian behaviour mapping, photographic documentation, and thematic analysis. Master plan drawings and cross-sections were used as reference tools to compare intended design outcomes with on-ground conditions.

4.2 Site Observation

Systematic field observations formed the primary empirical basis of the study. The entire stretch of Gandhi Bazaar Main Road—from D.V.G. Road to K.R. Road—was surveyed during morning, afternoon, and evening periods to capture variations in activity intensity. Observations assessed pedestrian pathway continuity, effective width, surface quality, gradients, and material conditions.

Attention was given to elements that constrained movement, including vending spillovers, utility infrastructure, parked vehicles, tree pits, and shopfront extensions. The spatial relationship between sidewalks and commercial edges was examined to understand how built frontage conditions influenced crowding and pedestrian flow. Field notes, sketches, and geotagged photographs were recorded to ensure systematic documentation.



Figure 17*: vehicular Traffic at morning 8 in a weekday*
Source- *Author*

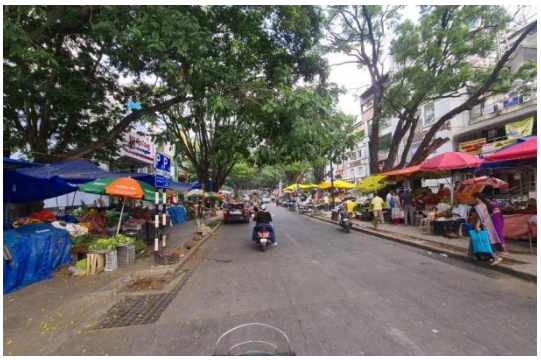


Figure 18: *Evening Pedestrian and vehicular traffic and vending activity*
Source: *Author*

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4.3 Pedestrian Behaviour Mapping

Pedestrian Behavioural mapping was conducted during peak (8:00–11:00 a.m.; 5:00–8:00 p.m.) and off-peak (1:00–4:00 p.m.) periods to identify movement patterns and spatial negotiation strategies. Directional flows, congregation points, mid-block crossings, and desire lines were mapped to understand how pedestrians adapted to constraints.

High-activity nodes near flower markets, eateries, schools, and religious institutions were examined for density variations and conflict zones. The mapping also distinguished temporal differences, noting market-oriented activity in the morning and increased recreational use in the evening

4.4 Photographic Documentation

Photographic documentation supplemented field observations by capturing material conditions, landscape features, signage, street furniture, drainage systems, and congestion points. Comparative analysis between planned design drawings and actual street use highlighted deviations resulting from informal practices. This visual record supported thematic interpretation under the safety–comfort–pleasure framework.



Figure 19: *Key Junction and Pedestrian crossing* ***Source:*** *Author*



Figure 20: *Parking and street vending in site* ***Source:*** *Author*

5. Analytical Parameter

The evaluation of Gandhi Bazaar's pedestrian environment is structured around three interrelated dimensions: safety, comfort, and pleasure. These parameters provide an interpretive lens for examining how spatial design, infrastructural interventions, and everyday practices interact within a traditional market setting. The analysis considers both the outcomes of recent streetscape redevelopment and the ongoing influence of pedestrian, vendor, and vehicular dynamics on the quality of the public realm.

5.1 Safety

Safety constitutes the primary condition for walkability. It concerns the degree to which pedestrians are protected from vehicular conflict and whether spatial organization clearly communicates movement priorities. The redevelopment introduced widened sidewalks, improved lighting, and raised pedestrian crossings, contributing to better visibility and moderated traffic speeds. These interventions have strengthened the structural framework for pedestrian movement, particularly during periods of lower traffic intensity.



Figure 21: *Encroachment of the pedestrian walkway by private two-wheeler parking.* **Source:** *Author*



Figure 22: *Redeveloped street with organized pedestrian, on Street parking and vehicular movement.* ***Source:*** *Author*

Informal parking and temporary encroachments frequently reduce effective footpath width, compelling pedestrians to enter the carriageway. Mid-block crossings are common due to the linear arrangement of commercial activities, resulting in movement patterns governed more by convenience than by formal crossing points. During high-activity events such as the Kadalekai Parishe, the concentration of pedestrians and unrestricted vehicular access intensifies these tensions. Although reduced speeds create a shared-space condition, reliance on informal negotiation introduces unpredictability, particularly for vulnerable users. Consequently, safety improvements are present but not fully institutionalized within the spatial system.

5.2 Comfort

Comfort refers to the physical and environmental qualities that support sustained and easeful walking. The upgraded paving, standardized curbs, and integrated drainage have enhanced surface continuity in several segments of the street. The mature tree canopy significantly improves thermal conditions, contributing to microclimatic comfort and encouraging slower movement and extended engagement diminish ease of movement.



Figure 23: *Pedestrian walkway shared with vending and parked vehicle*
***Source**: Author*



Figure 24: *Encroachment by Private two-wheeler parking and vendor spillover onto the pedestrian walkway*
***Source:** Author*

Yet comfort varies across the bazaar. In high-activity zones, vendor spillovers, stacked goods, signage elements, and temporary seating compress walking space and create bottlenecks. Although the nominal design width of footpaths is adequate, the effective pedestrian corridor is often reduced. Variations in lighting intensity and limited availability of resting areas further affect perceived comfort, particularly in evening hours. These findings suggest that comfort depends not only on infrastructural provision but also on the regulation and maintenance of spatial occupation.

5.3 Pleasure

Pleasure captures the experiential and cultural dimensions of the pedestrian environment. Gandhi Bazaar's enduring strength lies in its sensory richness and layered identity. Traditional commerce, religious landmarks, and everyday social exchanges generate a vibrant atmosphere defined by colour, aroma, and sound. Flower vendors, food stalls, and long-established shops contribute to a dynamic streetscape that reinforces collective memory and place attachment.

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Figure 25: *Traditional flower vending the cultural heritage of Gandhi Bazaar.*
Source: *Author*



Figure 26: *Spillover of informal eateries onto the pedestrian walkway*
Source: *Author*

However, the same vibrancy can lead to spatial saturation during peak periods. Overcrowding reduces personal space and limits opportunities for pause and informal gathering. The absence of dedicated seating courts or small social pockets restricts prolonged engagement with the environment. Nevertheless, the street sustains a strong sense of belonging rooted in familiarity and cultural continuity. Pleasure in this context emerges less from spatial order and more from social interaction and ritual presence.

6. Analysis and Discussion

The findings indicate that walkability in Gandhi Bazaar is not a fixed outcome of physical redesign but a negotiated condition shaped by spatial intent, everyday behavioural practices, and institutional capacity. While the recent redevelopment has enhanced the material quality of the street, its long-term performance depends on how effectively the redesigned environment accommodates the social and economic rhythms characteristic of a traditional market. The interaction between formal planning and lived urban practices therefore becomes central to understanding the street's functionality.

6.1 Relationship Between the Intent of Design and User Preferences

The redevelopment envisioned Gandhi Bazaar as a structured pedestrian corridor supported by wider footpaths, organized vending areas, improved paving, and clearer spatial demarcation. These interventions were intended to rationalize movement patterns and prioritize pedestrian circulation. In practice, however, the spatial configuration encounters the fluid and adaptive nature of bazaar activity. Informal vending, temporary merchandise displays, and service-related spillovers remain integral to the street's daily operations. Rather than functioning as peripheral disruptions, these activities constitute the economic backbone of the bazaar.



Figure 27: *Informal vending occupying pedestrian space.*
Source: *Author*



Figure 28: *Pedestrian movement affected by street vending.*
Source: *Author*

As a result, the intended cross-sectional hierarchy is frequently reinterpreted through everyday use. Pedestrian pathways are reshaped by dynamic occupation, particularly during peak hours and festive periods. This divergence underscores the limitations of rigid spatial allocation in contexts defined by temporal variation, fluctuating densities, and overlapping functions. The findings suggest that effective pedestrian design in heritage markets must incorporate flexibility and adaptive tolerance rather than rely solely on static geometric clarity.

6.2 Safety improvements vs vehicular movement

Safety outcomes reflect both infrastructural enhancements and behavioural negotiation. Traffic-calming measures, raised crossings, and improved illumination have moderated vehicular speeds and enhanced pedestrian visibility. These interventions contribute to baseline improvements in movement predictability. Nevertheless, informal mid-block crossings and parking intrusions persist, particularly in commercially dense segments.

The coexistence of pedestrians and slow-moving vehicles creates a quasi-shared environment in which movement is regulated more through social cues than through physical segregation. While such arrangements may function adequately for regular users familiar with the street's rhythms, they introduce uncertainty for children, elderly individuals, and persons with disabilities. The absence of consistent enforcement or continuous physical deterrents weakens the permanence of pedestrian priority. Consequently, safety remains contingent upon user awareness rather than fully embedded spatial control.

6.3 Comfort and the Walking Atmosphere

Comfort along Gandhi Bazaar is unevenly distributed. In stretches where pedestrian corridors remain unobstructed and shaded by mature tree canopies, walking conditions are perceptibly pleasant. The combination of improved paving and climatic buffering encourages slower movement and supports prolonged engagement with shopfronts.

However, zones of intense commercial interaction reveal how overlapping functions compress available space. Vendor clusters, stacked goods, temporary seating, and utility elements reduce effective walking width, even where nominal design dimensions are adequate. This compression leads to congestion and frequent route adjustments. The findings illustrate that infrastructural provision alone does not secure comfort; sustained management of spatial occupation is equally critical.

6.4 Pleasure, Cultural Existence, and Street Life

The experiential quality of Gandhi Bazaar remains its most enduring strength. The street's identity is sustained through ritual practices, seasonal markets, traditional retail, and daily social exchanges. These elements generate a multisensory environment characterized by colour, sound, and collective familiarity. Pleasure in this context emerges not merely from aesthetic coherence but from the continuity of cultural practices embedded within the built form.

Yet pleasure is closely tied to spatial balance. Excessive crowding during peak periods can reduce personal space and diminish opportunities for pause or informal gathering. The absence of dedicated social pockets limits the street's capacity to accommodate lingering beyond transactional exchange. Thus, experiential richness depends on maintaining equilibrium between density and spatial clarity.

6.5 Role of Management and Long-Term Feasibility

Across safety, comfort, and pleasure, governance and maintenance play decisive roles in sustaining pedestrian gains. Observed deficiencies—including surface deterioration, lighting inconsistencies, and parking encroachments—reflect gaps in post-implementation oversight rather than conceptual shortcomings in the design framework. Resistance from traders and residents further demonstrates that long-term success depends on participatory engagement and alignment with local economic realities.

Sustainable pedestrianization in heritage markets therefore requires adaptive regulatory mechanisms capable of responding to changing activity patterns. Continuous monitoring, collaborative stewardship, and flexible enforcement strategies are essential to reconcile formal design objectives with informal urban dynamics. Gandhi Bazaar illustrates that pedestrian-friendly streets in culturally dense contexts function as evolving systems rather than static design products.

7. Conclusion

The redevelopment of Gandhi Bazaar has enhanced the physical structure of the pedestrian environment, yet it has not fully resolved the inherent tensions of a traditional market street. While the street remains culturally vibrant and socially active, comfort is uneven and

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pedestrian safety is inconsistently achieved. This indicates that infrastructure improvements alone are insufficient to establish effective walkability in heritage contexts.

The study highlights that pedestrian environments evolve through the interaction of design intent, everyday practices, and cultural identity. Interventions such as widened sidewalks, improved paving, lighting, and organized vending have strengthened spatial clarity. However, informal activities, encroachments, and intermittent vehicular access continue to reshape the intended design, revealing the limits of purely design-driven approaches.

Within the safety–comfort–pleasure framework, outcomes remain varied. Safety benefits from traffic calming but is weakened by informal crossings and parking spillovers. Comfort improves through shading and surface quality yet is reduced by competing spatial uses. Pleasure remains the most resilient aspect, sustained by cultural continuity and social interaction.

These findings emphasize the need for adaptive governance, continuous maintenance, and stakeholder participation. Gandhi Bazaar demonstrates that pedestrian-friendly streets are evolving systems shaped by ongoing negotiation between design, use, and management.

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Residential Design Determinants in India: Balancing Personal, Cultural, and Environmental Priorities

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Abstract: Residential design in India is shaped by a complex interplay of personal preferences, financial constraints, climatic conditions, and cultural norms. This study aims to identify and analyze the most significant factors influencing house design within the Indian context. Employing a mixed-methods approach, we conducted structured surveys with homeowners across diverse regions and analyzed case studies of representative housing projects. The survey asked participants to rank the importance of factors such as personal preference, budget, resale value, climate, and cultural influences in their residential design decisions. The results indicate that personal preferences and budgetary considerations are the most critical determinants of residential design choices. However, cultural traditions and environmental factors also play substantial roles, particularly in regions with strong cultural identities or distinct climate challenges. Our findings suggest that future residential design in India must strive for a balance between individual aspirations and broader social and environmental needs to ensure sustainable and culturally resonant housing solutions.

Keywords: *Residential Design; Personal Preferences; Budgetary Constraints; Cultural Influences; Climatic Conditions*

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1. Introduction

Residential design is a multifaceted process influenced by a range of factors that vary across regions, socio-economic groups, and cultural backgrounds. In India, the diversity of climate zones, cultural traditions, and economic disparities results in a wide spectrum of housing styles and design priorities (Desai, 2018). Rapid urbanization and economic development have further transformed the landscape of residential architecture, introducing new construction technologies, materials, and changing aspirations among homeowners (Khosla, Sircar, & Bhattacharya, 2020). At the same time, traditional values and climate-responsive strategies continue to inform design decisions, particularly in rural and peri-urban areas (Mehrotra, 2011). This paper seeks to systematically explore the most significant factors influencing residential design in India by analyzing survey data from homeowners and insights from relevant literature. By examining the intersections of personal preference, economic capacity, climate adaptation, and cultural heritage, the study aims to provide a comprehensive understanding of the evolving dynamics of Indian residential design.

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2. Methodology

This study utilized a mixed-methods approach, combining quantitative and qualitative data to achieve a comprehensive analysis of the factors influencing residential design in India. A structured survey was distributed to a diverse group of Indian homeowners across multiple regions, collecting demographic data and asking participants to rank the importance of factors such as personal preference, budget, resale value, climate, and cultural influences in their housing decisions. The survey instrument was piloted and refined for clarity and validity. In total, 70 anonymized responses were collected.

To supplement the survey data, *six* case studies of bungalow projects were selected for in-depth analysis. These case studies involved site visits, architectural plan reviews, and semi-structured interviews with the architects responsible for each project. The interviews explored the architects' perspectives on influential design factors and the challenges of balancing client expectations with contextual realities. This triangulation of survey results, case studies, and expert interviews enhanced the validity and reliability of the findings (Creswell & Plano Clark, 2018).

3. Literature Review: Evolving Discourses on Residential Architecture in India

Research on Indian residential architecture over the last decade reflects a dynamic transition from socio-economic concerns and tradition-based practices to new emphases on sustainability, technology, inclusivity, and post-pandemic lifestyle shifts. Studies between 2016 and 2023 show how varied forces like cultural, climatic, economic, and sociological shape housing design amid rapid urbanization and technological advancements.

Khanna and Rao (2016) addressed the implications of India's rapid population growth on residential space availability. Their analysis using demographic data, GIS mapping, and urban planning testimonies revealed shrinking apartment sizes by nearly 25 percent over two decades in cities like Delhi and Mumbai. The study linked these shortages with the proliferation of informal settlements and deteriorating housing quality, stressing the need for anticipatory urban planning to ensure equitable access. This early work set the foundation for subsequent attention to affordability and sustainability.

Gupta and Singh (2017) focused on the role of socio-economic disparities in shaping Indian housing. Surveys and interviews highlighted stark contrasts between wealthier neighbourhoods, offering well-ventilated and spacious homes, and low-income settlements suffering from overcrowding and poor sanitation. Despite targeted programs such as the Pradhan Mantri Awas Yojana, quality and spatial standards remain neglected in lower-income housing.

Sharma and Rao (2017) examined the continued influence of Vastu Shastra on modern residential design. Surveys across Delhi, Mumbai, and Kolkata revealed that more than 60 percent of new urban homes incorporated Vastu principles related to orientation, spatial organization, and placement of openings. While some architects welcomed Vastu's alignment

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with client expectations, others critiqued its restrictive nature. The persistence of Vastu demonstrated the enduring role of cultural traditions amid modernization.

Regional climatic adaptation came into sharp focus in Singh and Patil's (2018) study. They demonstrated how arid Rajasthan necessitates thick walls and courtyards, Kerala's humid tropics require open plans and sloping roofs, and Himachal Pradesh's snowy climate demands wooden structures with steeply pitched roofs. The authors criticized contemporary designs that prioritized aesthetics and rapid construction at the expense of climatic responsiveness, leading to energy inefficiencies.

Dixit and Nair (2018) further compared traditional and modern housing. Their study found that rural homes, constructed with mud, clay, and stone, ensured durability and environmental adaptability, while modern homes in Delhi and Bengaluru emphasized steel, glass, and concrete aesthetics. These modern trends, however, often ignore environmental suitability, increasing energy consumption. The authors proposed hybrid models merging environmental wisdom with contemporary appeal.

Bhatia and Kumar (2019) advanced the exploration of cultural contexts, analyzing traditions' role in shaping residential forms. Their case studies highlighted Rajasthan's courtyard planning, Kerala's open layouts, and Tamil Nadu's verandas as reflections of deep-rooted social practices. The authors concluded that integrating cultural heritage into modern housing ensures practical relevance and continuity.

Concurrently, Mishra and Gupta (2019) studied how urbanization shaped rural housing. They documented a shift from traditional mud and bamboo materials to concrete and steel in Maharashtra and other regions. While modern materials enhanced durability, they reduced thermal comfort and raised maintenance costs, underscoring the risks of disregarding local climate responses in rural transformations.

Rao and Sharma (2020) investigated sustainable housing practices, focusing on energy performance and material efficiency. They found that despite exemplary cases in Bengaluru and Pune—featuring green roofs, solar panels, and water-recycling systems—wider adoption faced hurdles due to high initial costs and low awareness. Enhanced public education and policy incentives were recommended to bridge this gap.

Sharma and Rathi (2020) emphasized the need for inclusive housing design. Their study in Ahmedabad and Chennai showed how ramps, adaptable interior layouts, and universal design features significantly improved accessibility for elderly and differently abled residents. These inclusive measures raised resident satisfaction but faced barriers due to developers' reluctance to invest in ramps and accessibility features without policy support.

Affordability emerged as a critical area in Mehta and Joshi's (2021) study, which identified modular construction, locally sourced materials, and adaptive layouts as potential solutions. For instance, precast concrete reduced costs by up to 30 percent and building timelines by 25 percent. However, cramped unit sizes in urban projects remained a barrier to livability.

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Choudhary and Singh (2021) assessed slum redevelopment challenges through case studies in Mumbai and Delhi. Their findings noted that projects such as the Dharavi Redevelopment often lacked communal spaces and displaced residents, severing social support structures. Further, many redeveloped units failed to include adequate sanitation or integration with public transport, highlighting shortcomings in livability. The study called for holistic redevelopment that retains community ties and provides essential services.

From a sociological angle, Sharma and Pillai (2021) documented the rise of gated communities in Gurgaon and Hyderabad. These areas offer exclusiveness, enhanced security, and modern lifestyle amenities, but have also deepened socio-economic divides. Often creating infrastructural self-sufficiency, gated communities risk isolating residents from city-wide networks, intensifying segregation.

Technological transformation gained prominence in Verma and Agarwal's (2022) work, which found that in Bengaluru, nearly half of new homes feature smart systems for lighting, temperature control, and security. This led to energy savings of up to 20 percent, but adoption was constrained by affordability and emerging privacy concerns. The digital divide underscores the disparity in who benefits from these advances.

In parallel, Verma and Iyer (2022) analyzed prefabricated housing solutions. Case studies in Pune and Chennai showed that prefabricated complexes significantly reduced costs and construction duration. A 200-unit apartment project in Pune was completed in just six months, versus 18–24 months for conventional construction. Despite these benefits, market adoption has been limited due to misconceptions about construction quality and limited skilled labour availability.

Finally, Verma and Arora (2023) addressed post-pandemic residential trends, where housing priorities shifted toward wellness, adaptability, and access to open spaces. Surveys across Mumbai and Bengaluru revealed heightened demand for better ventilation, natural lighting, terraces, and flexible room layouts compatible with home offices. Proximity to gardens or balconies has become an indicator of desirability, even raising property values. The study concluded that pandemic-driven spatial revaluations will profoundly reshape future development priorities.

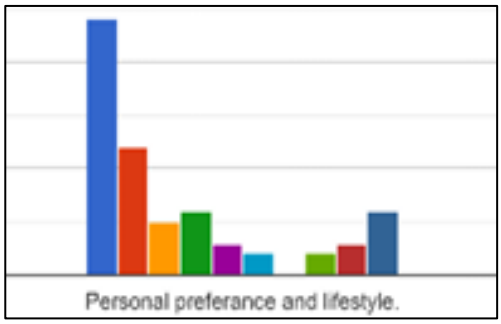
Overall, Indian residential architecture scholarship reflects a dynamic balance between continuity of tradition, environmental imperatives, and new demands of technology and lifestyle. Together, these studies reveal that Indian residential architecture is shaped by a dynamic intersection of culture, climate, technology, socioeconomics, and global events demanding innovative, inclusive, and context-sensitive design solutions for the future.

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4. Data & Analysis

Responses were analyzed in the context of the ranking provided by the respondents for the various factors.

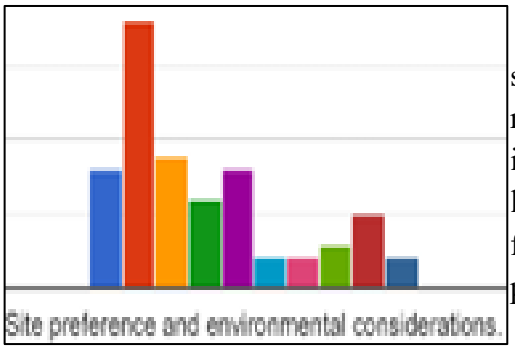
Personal Preference and Lifestyle:



This factor was ranked *First* by most participants, with 60% of them assigning it the highest priority. Personal preferences were identified as the most influential factor in residential design. Respondents consistently ranked their tastes and lifestyles as the top consideration when making design decisions, indicating that homeowners prioritize creating spaces that reflect their individual needs.

(**Figure 1:** Chart for Personal Preference and Lifestyle)

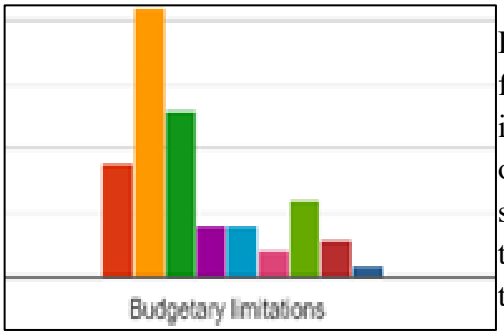
Site Preference and Environmental Considerations:



Most often ranked *Second* by 50% participants, suggesting strong importance as well. Preferences regarding site and location also played a moderate role in influencing home design decisions. The choice of location was often influenced by proximity to work, family, or amenities, but it was not ranked as high as personal preference or budget constraints.

(**Figure 2:** Chart for Site Preference and Environmental considerations)

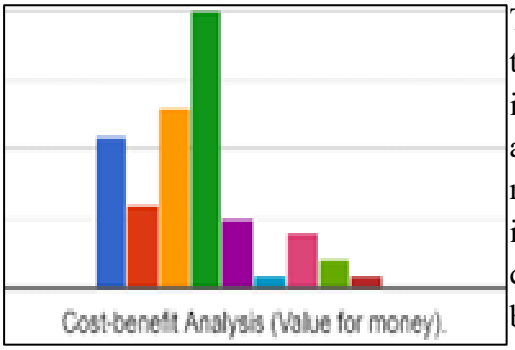
Budgetary Limitations:



Budget constraints are ranked as the *third* most important factor influencing house design. Many respondents indicated that budget was a significant limiting factor, often ranking it just below personal preference. This suggests that while people have clear ideas about what they want in their homes, financial limitations often shape the final design.

(**Figure 3:** Budgetary Limitations)

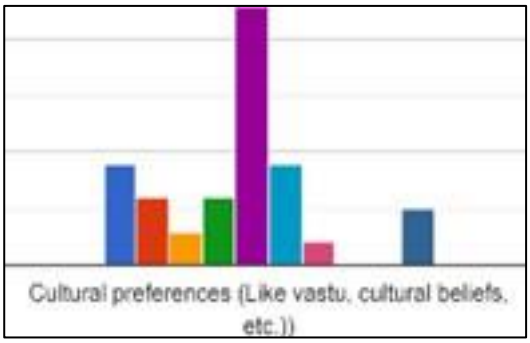
Cost-Benefit Analysis (Value for Money):



This factor shows mixed rankings, with a slight bias toward *fourth* place, indicating it's considered important but not dominant. Value for money emerged as another critical consideration, particularly for middle-income households. Respondents stressed the importance of balancing cost with functionality and quality. This factor was frequently ranked just after budget, indicating that homeowners are aware of the need to maximize their investments.

(**Figure 4:** Chart for Cost-benefit analysis)

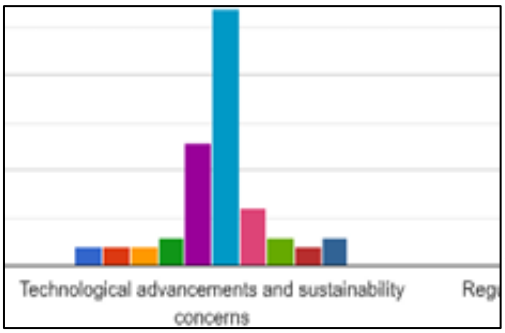
Cultural Preferences (e.g., Vastu, Cultural Beliefs):



Most participants ranked this factor *fifth,* implying moderate importance in their decision-making process. Cultural factors, including traditional beliefs like Vastu Shastra, were important for some respondents, particularly in certain regions. However, cultural preferences ranked lower than practical considerations such as budget and functionality.

(**Figure 5:** Chart for Cultural preferences)

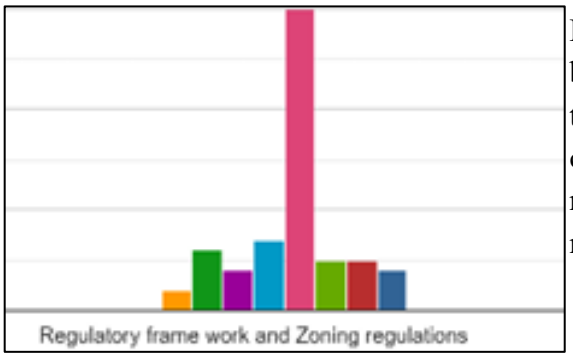
Technological Advancements and Sustainability Concerns:



Technological advancements and sustainability concerns were ranked *sixth*. Interest in technological innovations and sustainable housing design was noted, although these factors were not ranked as top priorities. Homeowners demonstrated some awareness of energy-efficient designs, solar power, and smart home systems, but these were seen as secondary to more immediate concerns like cost and space.

(**Figure 6:** Chart for Technological advancements and sustainability concerns)

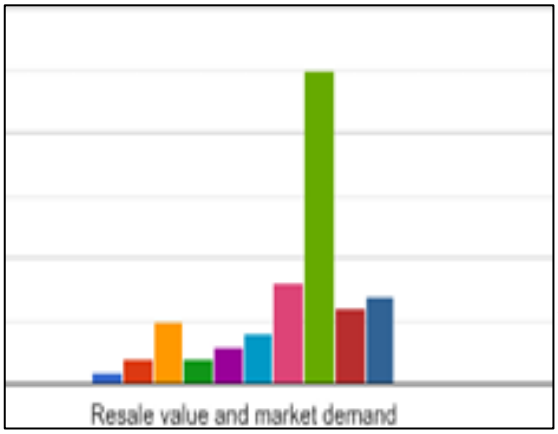
Regulatory Framework and Zoning Regulations:



Regulatory issues, including zoning laws and building regulations, ranked *seventh* and lowest in terms of influence on design decisions. While compliance with these rules is necessary, they were not viewed as a major factor in the design process for most homeowners.

(**Figure 7:** Chart for Regulatory framework and zoning regulations)

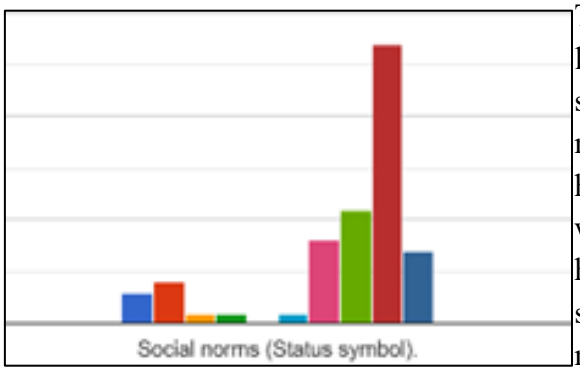
Resale Value and Market Demand:



Consistently ranked *eighth* by all participants, indicating it's considered but not to be a major influence on design decisions. Although resale value and market demand were not ranked as highly as others, they still influenced residential design decisions. Respondents recognized the potential long-term financial benefits of investing in a home that retains or increases its value in the real estate market. However, this was not a primary concern for most.

(**Figure 8:** Chart for Resale value and market demand)

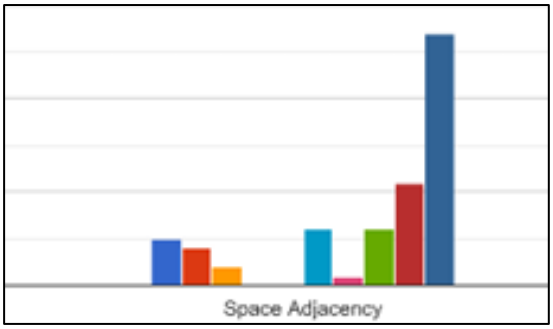
Social Norms (Status Symbol):



This factor was always ranked *ninth*, reflecting its low importance in the decision-making process. The social perception of a home as a status symbol was of medium importance. Some respondents considered how their homes might be viewed by others, but this was not a driving factor for most. However, among higher-income groups, features such as large living spaces and luxury materials were more frequently mentioned.

(**Figure 9:** Chart for Social Norms)

Space Adjacency:



Ranked *last* by all participants, suggesting it is the least important factor when making design decisions. The layout and connection between rooms, referred to as space adjacency, was moderately ranked. Homeowners value the efficient use of space, especially in urban areas where homes tend to be smaller. While functional spaces that allow for easy movement were appreciated, they were less prioritized compared to personal preference and budget.

(**Figure 10:** Chart for Space adjacency)

5.Discussion:

The survey findings offer a comprehensive insight into the predominant factors shaping residential design choices in India. It is evident that personal preferences and budgetary limitations significantly influence homeowner decisions, underscoring a priority to create living environments tailored to individual needs while operating within financial constraints. This trend aligns with findings in housing research, which emphasize the centrality of economic considerations in residential planning (Singla, 2019). Although cultural influences retain relevance in design decisions, they are largely superseded by practical considerations such as cost efficiency, usability, and overall value for money. The relatively modest importance accorded to technological advancements in the survey reflects a nascent stage of adoption of smart home and sustainable technologies among the broader homeowner demographic, consistent with recent studies highlighting that while awareness of smart technologies is increasing, mainstream uptake remains limited due to affordability and perceived value (Designdekko, 2024; Epic Infrateck, 2024).

These survey outcomes corroborate extant literature that attributes a continued role to cultural and environmental factors in Indian residential architecture. Bhatia and Kumar (2019) underscore the enduring impact of cultural identity and environmental responsiveness on architectural expression, while Singh and Patil (2018) highlight the integration of climate-sensitive solutions emblematic of Indian housing traditions, reinforcing the notion that successful residential designs often negotiate a balance between cultural heritage and contemporary needs. Moreover, vernacular architecture studies affirm the thermal comfort and social functionality inherent in traditional Indian designs, such as courtyard houses, which embody sustainable responses to local climates and social living arrangements (Hazarika, 2022).

However, the present survey reveals that in contemporary Indian home design, immediate pragmatic factors—budget constraints, personal preferences, and the pursuit of value—take precedence over cultural symbolism or emerging technological trends. This is reflective of the socio-economic realities confronting a majority of Indian homeowners who prioritize

affordability and functional utility. In alignment with this, recent research on user customization within urban Indian community housing highlights the importance of personal agency and adaptation in residential spaces to meet practical and psychological needs, often mediated by financial and spatial limitations (Ugrani, 2021).

In summary, while Indian residential architecture continues to be influenced by deep-rooted cultural and environmental considerations, the dominant drivers of design choices today are economic and personal, emphasizing affordability, functionality, and customization, with technological innovations yet to achieve widespread integration among mainstream homeowners.

6. Conclusion

This study provides a nuanced understanding of the complex factors influencing residential design choices in India, elucidating that personal preferences, budget constraints, and the pursuit of value for money are the primary determinants for homeowners. While cultural and environmental considerations maintain their importance, they commonly assume a secondary role in the decision-making hierarchy. This prioritization reflects the socio-economic realities faced by many Indian homeowners who must navigate affordability and functionality alongside traditional values.

As India undergoes rapid urbanization and the demand for housing escalates, the findings underscore the need for future residential designs to harmonize the multifaceted interplay of individual aspirations, cultural heritage, and pragmatic considerations. Current market analyses indicate an ongoing shift toward larger, more flexible spaces that accommodate hybrid lifestyles, such as work-from-home setups, multigenerational living, and wellness-centric environments (Trident Realty, 2024). The adoption of smart technologies and sustainable design principles is increasingly integrated into architectural practice, though affordability remains a core constraint that tempers their widespread acceptance.

The trajectory of India’s residential sector suggests that the integration of sustainability measures—such as energy-efficient systems, water conservation techniques, and green certifications—is gaining momentum, but these are often contextualized within budgets that do not compromise basic functional and economic demands (Mordor Intelligence, 2025). Furthermore, the expansion of senior-inclusive and health-supportive features in housing design reflects demographic transitions and evolving lifestyle needs. This evolution complements the cultural emphasis on family cohesion and respect for elders, demonstrating that traditional values continue to inform contemporary design imperatives, albeit mediated through modern frameworks.

Therefore, the conclusion drawn from this research is that Indian residential architecture is in a dynamic phase of convergence where economic pragmatism, personal customization, and cultural considerations coexist and influence design outcomes. While technological advancements and sustainability will increasingly shape future housing developments, their adoption will remain contingent upon cost-effectiveness and demonstrable utility. Developers

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and designers must therefore advance context-sensitive, affordable solutions that embrace both innovation and cultural rootedness to effectively respond to the diverse and growing Indian housing market.

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Enhancing employee well-being and productivity in office spaces through biophilic design and ergonomics

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Abstract - In today's rapidly expanding world, people spend about 70–90% of their time indoors, and many of them work in offices. Poor work environment conditions can negatively impact employees' health and safety, error rates, innovation, cooperation, absenteeism, and productivity. Researchers claim that 86% of productivity problems are related to the physical conditions of the workplace. To address these issues, a holistic approach to workplace design is needed.

By incorporating biophilic and human-centered design approaches, the design of workplaces can positively impact users' physical, psychological, cognitive, and social health. This research aims to explore the **impact of biophilic design and ergonomic principles**, which are two key components of a human-centered workplace design approach, on employee well-being in office environments. Integrating natural elements into ergonomic furniture design can enhance the restorative quality of workspaces, contributing to improved mental health.

Specifically, the study will analyze **key aspects of biophilic design** and investigate how these elements influence **job satisfaction and productivity**. The methodology includes 2 questionnaire surveys, study of 3 cases and interviews to capture employees' perceptions of their work environment, stress levels, job satisfaction, and productivity. Analysis revealed the synergistic effects of integrating biophilic design with ergonomic principles on overall employee well-being and performance. Employees **preferred real plants over artificial plants** in their workspaces. They preferred adjustable workstations for workspaces to bring flexibility in the office layout. Also recommended provision for recreational areas like meditation rooms, library, café.

Keywords: Office Spaces; Biophilic Design; Ergonomics; Employee Well-Being; Mental Health and Productivity

1. Introduction

Poor work environment conditions affect employees' health and safety, error rates, innovation, cooperation, absenteeism, and productivity. Researchers claim that 86% of productivity problems are related to the physical conditions of the workplace. The investigation of office environmental conditions in workspaces, such as indoor air quality, noise, lighting, and temperature, indicates that environmental factors affect employees' attitudes, behavior,

satisfaction, performance, and productivity by influencing their comfort. (Ahmad Baleshzar et al., 2022).

Prioritizing employee well-being in office spaces directly translates to increased productivity, engagement and job satisfaction. Supporting employees in achieving a healthy work-life balance is crucial for reducing stress and burnout (Ozerek, 2023).

Research demonstrates that by incorporating biophilic and human-centered design approaches, the design of the workplaces can positively impact users' physical, psychological, cognitive, and social health (Wallmann-Sperlich et al., 2019).

When offices are in dense urban areas where employees cannot see natural landscapes from their windows, incorporating indoor plants can help create a more restorative and visually appealing work environment. Plants will allow for the creation of more natural surroundings and the addition of a relaxing atmosphere to the space. They can also be utilized for decoration, making your area feel even more friendly (Elantary, 2024).

The biophilic design hypothesis remarks humans are innate to nature and brings nature and natural systems into built environments for their potential health benefits. Consequently, biophilic design has become increasingly popular in recent years. (Yin et al., 2019).

Aside from vegetation, Use Natural Materials: The use of natural materials, such as wood, stone, and natural fibers, is a crucial principle in biophilic design. These materials create a tactile and visually appealing environment that reflects the textures and patterns found in nature. They can evoke a sense of warmth, authenticity, and biophilic connection. Also, designing spaces to optimize natural light and incorporate views of greenery or natural landscapes helps create a sense of connection with the outdoors (Browning & Ryan, 2020).

Studies have revealed a variety of contributing factors to musculoskeletal discomfort including increased job demands and more hours working at a computer and a lack of specific ergonomic features in the workstations and office buildings (Nelson & Silverstein, 1998).

There are several proven benefits of a strong workplace ergonomic process. Ergonomics reduces costs, it improves the quality of products, ergonomics improves employee engagement, and it creates a better safety culture. The problem of an improper workstation design may be due to a lack of knowledge or inappropriate application of ergonomic principles (Jayathilaka & Karunarathna, 2021).

Features of an office such as people, building space, equipment, furniture and the environment must fit together well for workers to feel healthy and comfortable and be able to work efficiently and productively. Workstation designs significantly affect working posture, which in turn, contributes to physical symptoms (Chandwani et al., 2019).

There is a strong and increasing trend worldwide in open-planned offices instead of small office rooms. Open-plan offices are favored because of, e.g. lower building expenses due to the smaller number of partitions, lower rent costs due to higher worker density, better adjustability and better access of daylight especially in deep-framed buildings. But some argue that the lack

of acoustic and visual privacy, increased distraction by noise, reduced workstation size, uncontrollable social contacts and interruptions are the most feared features of open-plan offices (Kaarlela-Tuomaala et al., 2009).

For instance, integrating natural elements into ergonomic furniture design can enhance the restorative quality of workspaces, contributing to reduced stress levels and improved mental health.

Significance / aim

This research aims to explore the impact of biophilic design and ergonomic principles on employee well-being and productivity in office environments.

Research questions

1. What different designs are being incorporated in office spaces?

2. How do biophilic and ergonomic office designs interact to enhance the workplace and employee's task efficiency?

3. Which are the main elements of biophilic design that have a major impact on the productivity and potential of the employees?

4. How are these attributes explored in the built form of offices in terms of architectural elements of the case studies?

2. Literature Review

2.1 Understanding Office spaces

Office space design and its importance is increasing with the average hours spent at work and as the nature of work is becoming more sedentary, especially in knowledge sectors. Work and family, while being interdependent, demand different kinds of efforts and time from both ends, straining and rising behavior-based conflicts for an employee. (Keerthi et al., 2024) In general, studies of the ambient features in office environments—including noise, lighting, temperature, existence of windows and others; suggest that such elements of the physical environment influence employees' attitudes, behaviors, satisfaction and performance (Kamarulzaman et al., 2011).

The design of the office environment is closely related to the perception of environmental factors. Hence, it is necessary to investigate the influence of office types on employees' satisfaction along with the office environment and the psychological concepts closely related to the office design (Bodin Danielsson & Bodin, 2008).

2.2 Introducing Biophilic Design in Offices

From the perspective of psychology, humans have a need to be close to nature, and nature also provides cultural and social values to humans. Biophilic design has a robust evolutionary theoretical framework with different design patterns (Gao et al., 2023).

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Table 1. Nature & Human-beings

BIOPHILIA HYPOTHESIS	
Biophilia	It is defined as evolutionary dependence on nature for survival and personal gratification.
Dwelling and Occupants	The emotional need for nature came from the emotion inherited from the experience and dwelling choice.
Restorative Environment	Proposes that excessive consumption of human brain functions leads to mental stress, further the interaction with nature does not require much energy, it helps to restore exhausted attention.

Source: (Alaqqad & Yedekci, 2024)

Biophilia has many uses that help transform mundane settings into stimulating environments whether by engaging with nature, by interacting with animals, by walking at a park, or by just having a view of greenery from home or workplace. the two basic dimensions of biophilic design are organic dimension and vernacular dimension.

- The term organic dimension refers to shapes and forms in the built environment that reflect the affinity for nature either directly, indirectly, or symbolically.
- The term place-based or vernacular dimension tends to be used to refer to landscapes and buildings that link to the culture and ecology of a locality or geographic area.

Together, It makes a framework that enhances the setting or place accordingly (Abdul Tharim, 2022).

2.3 Emphasizing Ergonomics in Offices

Nowadays most of the offices are based on the concept of non-territorial or free address offices in which a given desk, office or workstation is intended to be used by different people at different times. Ergonomics in the office environment ranges from business process analysis to workplace design including furniture, equipment and computer systems (Chandra et al., 2009).

Modern trends in office design continue to move towards creating the most comfortable and functional workspaces. Today's office premises must meet the requirements of not only functionality but also comfort and aesthetic appeal. **Ergonomics** plays an extremely important role in ensuring the physical comfort of the employee. Height-adjustable desks, ergonomic chairs and proper lighting create a healthy working environment and reduce the risk of health problems (Ahliullin et al., 2023).

Office layout is basically defined as the systematic arrangement of office equipment, machines and furniture and providing adequate space to office personnel for regular performance of work with efficiency. Office layout may also be classified into two categories:

- Process Layout
- Group Layout

Faulty or improper arrangement of furniture, equipment and space for employees leads to waste of time and energy and increase in the cost of office operations (Özkan & Ulutaş, 2020).

2.4 Focus on Employee well-being

Certainly, for well-being, space matters. The characteristics of the interior space can be a demand, for instance by causing environmental stress, as well as a resource, for instance by facilitating relaxation and social cohesion. opportunities to adjust the environment mediate the experience of environmental stress and according to the attention restoration theory green spaces aid recovery from environmental stress (Colenberg et al., 2020).

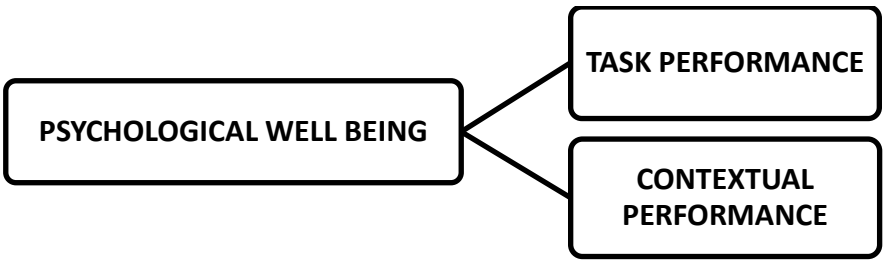
An overwhelming majority (87%) of workers would like their current employer to offer healthier workspace benefits, with options ranging from wellness rooms, company fitness benefits, sit-stands, healthy lunch options and ergonomic seating.

Seventy percent of offices today are open plan, and the open plan layout can be fantastic. But it really needs to be implemented correctly with employee productivity and happiness in mind. That is why one company is addressing the growing need for privacy in the workplace with their phone booth, a sound-proofed, ventilated booth (Kohll, 2019).

Environmental factors have imperative role to play in the effectiveness of office workers. Charles et al. has stated that indoor air quality and thermal comfort are most important factors for the worker's performance, satisfaction and well-being. Poor office environmental conditions can affect the worker's visual discomfort and thermal discomfort (Vimalanathan & Ramesh Babu, 2014).

In summary, a well-designed interior space can compensate for job demands and poor design can undermine job resources (Colenberg et al., 2020).

2.5 Mental Health and Productivity of Employees



Source: (Aquino et al., 2020)

Performance is a dynamic, multi-dimensional concept. High stressors correlate with the risk of recurrence of mental illness that negatively impacts the personal and professional lives of individuals. Employee performance increases significantly in a friendly, stress-free, and physically safe environment if he is psychologically and physically well (Aquino et al., 2020).

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One of the main reasons that withhold an organization from investing in the physical workspace to support employees' mental health is the absence of insights into the effectiveness of such investments. the freedom to adjust the workspace to personal preferences (e.g., furniture, decoration) relates to higher workspace satisfaction and increased productivity (Kropman et al., 2023).

Daily hours spent being sedentary (sitting), independent of levels of exercise or physical activity, are positively correlated with the risk of diabetes, cardiovascular disease, some cancers and premature mortality. In addition to physical pathology, the effects of sedentary behavior have been linked with negative mental outcomes such as depression, lower cognitive functioning, increased risk of dementia, and overall lower quality of life.

The use of scheduled micro-breaks results in decreased musculoskeletal pain, while demonstrating improvements in work quality, efficiency, and productivity. Also, physical activity at work improves psycho-physical performance, social relationships, and work performance (Radwan & Elsawy, 2022).

3. Methodology

The Methodology adopted involved a questionnaire survey along with live case studies and interviews of the employees.

Two online questionnaire surveys were undertaken out of which one was a photographic survey aimed to understand need and form/type of biophilia and ergonomics in the office environment from user point of view and the other being simple questionnaire to study mental well-being and job satisfaction rate of employees based on current office scenarios and what could be done to improve their productivity.

The online photographic Google Form was sent to 210 people, while valid responses obtained were **200** that made one of the final samples. Whereas other google form was also sent to almost 40 people, while valid responses were **30**. Thus, the final sample included total **230 people**, both male and female of different age groups and offices. The photographic survey had **20 questions** whereas other questionnaire had **40 questions** with a five-point Likert scale.

Besides, the activity performed in the available breakout spaces providing connectedness to nature explored. People's perceptions and aspirations about the availability of green spaces were examined. This was followed by investigating the user's satisfaction with office spaces regarding the natural element present in their surrounding along with the seating/furniture.

Different offices were also visited which include-

1. Architect's Office
2. Corporate Office
3. Government Office

To understand use and type of Biophilic elements in offices and its impact on employees. All three office buildings were designed by the same architect, reflecting a consistent environmental

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design approach that incorporates natural ventilation, daylight utilization, vegetation, and sustainable architectural principles to enhance occupant comfort and environmental performance. The interviews of the employees were also undertaken from all three offices for better understanding and improvisation.

4. Questionnaire Design

The questionnaires were about satisfaction with the indoor environmental quality in offices along with the overall office architecture. The questions addressed the employee's view regarding factors such as Preference for Green Spaces, Lighting Preferences, Furniture comfort, layout preference, sitting arrangements, Stress & Fatigue and scope for improvement of office spaces.

Important variables were scaled on five-point Likert scale with 1 = Very Important, 2 = Important, 3 = Neutral, 4 = Unimportant, 5 = Very Unimportant. To understand importance of certain variables

This five point Likert scale helped in analyzing employee preferences and the areas for improvement for employees' mental and physical well-being along with overall job satisfaction.

Research Method 1 – Questionnaires:

Following Charts represent the user Preference:

Demographic information of respondents-

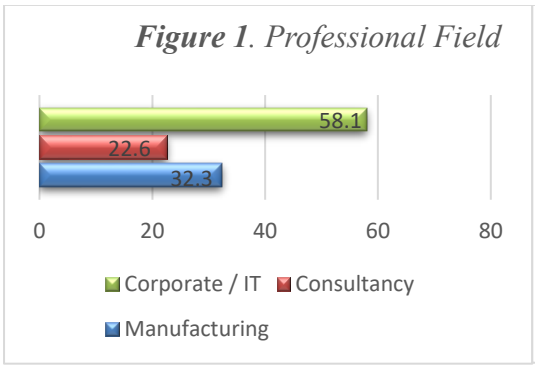


***Figure 1**. Professional Field*

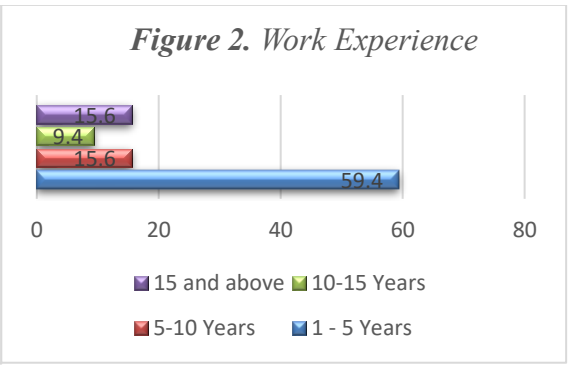


***Figure 2.** Work Experience*

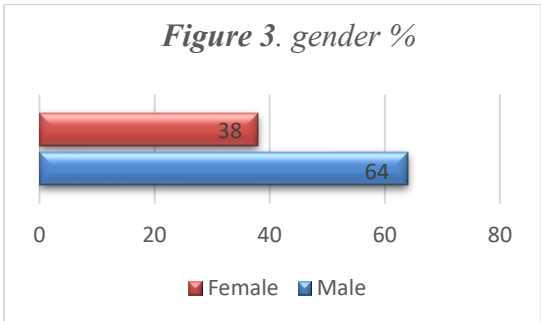


***Figure 3**. gender %*

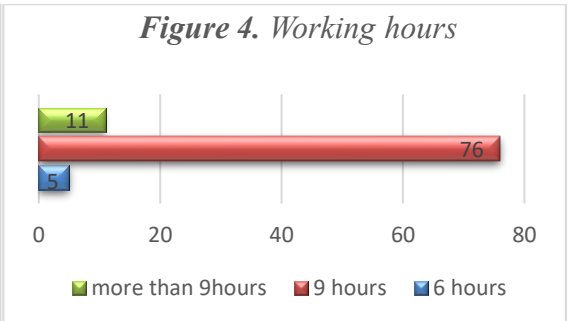


***Figure 4.** Working hours*

(**Source:** Author)

(*fig.1*) Majority of respondents (58.1%) belong to the **Corporate/IT sector**, followed by **Manufacturing** (32.3%) and **Consultancy** (22.6%). This suggests that most insights represent the views of employees from formal, desk-based work environments with structured office spaces.

(*fig.2*) It is found that **59.4%** of participants have **1–5 years of experience**, indicating a **young workforce** with early career exposure. Smaller proportions have **5–10 years (15.6%)**, **10–15 years (9.4%)**, and **15+ years (15.6%)** experience. This distribution reflects evolving preferences of a newer **generation of professionals** toward workplace design and comfort

(*fig.3*) Most of the respondents' report working **9 hours (76%)**, followed closely by those who work **more than 9 hours (58.1%)**. Only a small fraction report working **6 hours (5%)**. This suggests that most insights represent the views of employees who work **long hours**, with the standard workday being **9 hours or longer**. The data highlights a culture of extended working hours within the surveyed population.

(*fig.4)* The sample is heavily **male dominated**, with **64%** of respondents being Male compared to **38%** being Female. This suggests that the overall findings largely represent the experiences and views of **male employees**.

Green spaces and natural ventilation

Figure 5*.Green Spaces in Office*

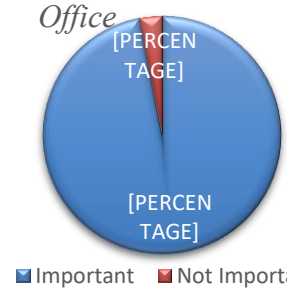
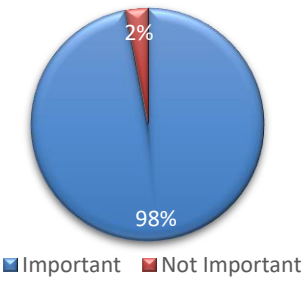


Figure 6.*Natural Ventilation*



(**Source:** Author)

(fig.5) A striking **97%** of respondents consider green spaces important, while only **3%** do not. This highlights a **strong preference for biophilic design elements** such as indoor plants, landscaped courtyards, or natural views within the workplace.

(fig.6) It is found that **98%** rated **natural ventilation as important**, and only **2%** did not. Access to fresh air and cross-ventilation are recognized as critical comfort factors in workplace design.

Users Satisfaction and importance with respect to Furniture design, visual connection with outdoors, recreational areas in the offices and natural light conditions.

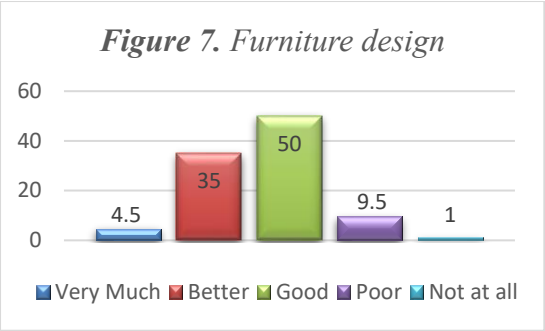


Figure 7. *Furniture design*

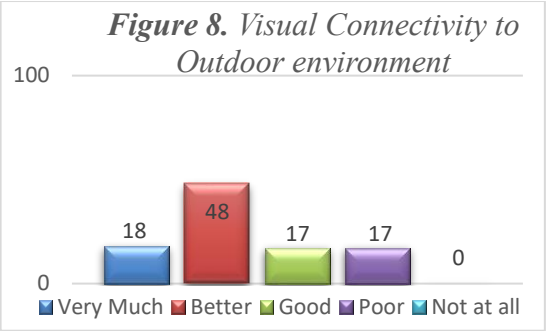


Figure 8. *Visual Connectivity to Outdoor environment*

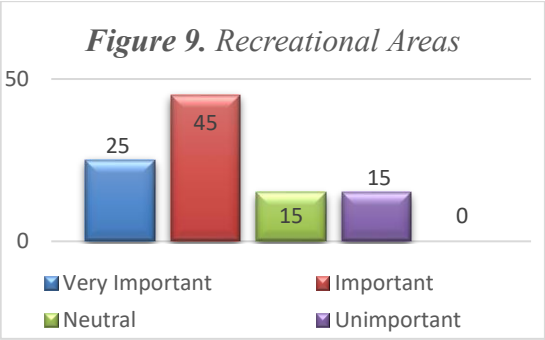


Figure 9. *Recreational Areas*

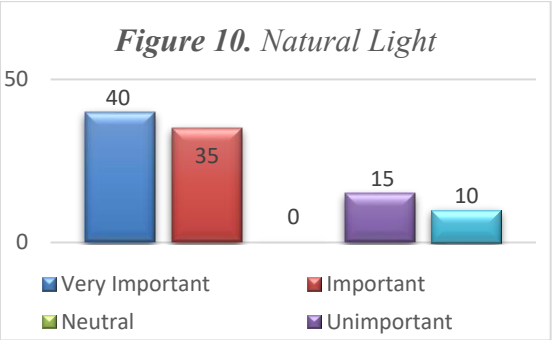


Figure 10. *Natural Light*

(**Source:** Author)

(*fig.7*) **50**% rated desks & chairs as good, **35%** as better, while smaller percentage rated it poor **(9.5%)** or very much **(4.5%).** Half of the respondents are satisfied with furniture ergonomics and aesthetics, though improvement in customization and comfort can be explored.

(*fig.8*) **48%** rated visual connectivity to outdoors as **better**, while **18% very much**, **17% good**, and **17% poor.** While many offices maintain visual access outdoors, **some dissatisfaction remains**, suggesting scope for improving natural views and daylight access.

(*Fig9*) **45%** rated recreational areas as **important**, **25% very important**, and **15% neutral.** Most users value recreational areas, emphasizing the growing demand for **relaxation and social spaces** in office design.

(*fig.10*) **40%** find natural daylight **very important**, **35% important**, **15% neutral**, and **10% unimportant.** Majority **value natural daylight** as an essential design factor for comfort and energy efficiency, with minor variation in perception.

These findings indicate that most of the respondents are content with their office environments overall but identify areas for improvement. Fifty percent or so of them rated desks and chairs as good in terms of decent ergonomics and appearance, although comfort level and customization should be upgraded. Visual access to the exterior was also given a positive rating by most but some grumblings indicate greater provision of effective natural views and daylighting should be made. Besides, numerous respondents emphasized the necessity of recreational areas, highlighting the increased importance assigned to relaxation and social interaction within the workplace. Natural lighting was identified as a primary concern, with many respondents viewing it as a requirement for comfort and efficiency.

Necessity of workspace flexibility, ambience & colour scheme and recreational areas –

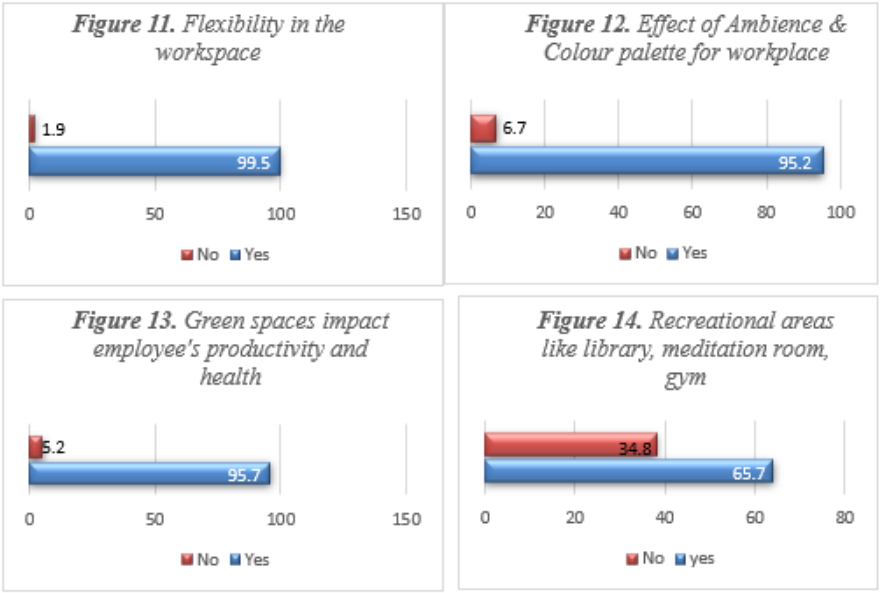


Figure 11. *Flexibility in the workspace*

Figure 12. *Effect of Ambience & Colour palette for workplace*

Figure 13. *Green spaces impact employee's productivity and health*

Figure 14. *Recreational areas like library, meditation room, gym*

(Source: Author)

(*fig.11*) **99.5%** agreed flexibility is important. This indicates **strong preference for adaptable layouts and furniture**. It enhances comfort, collaboration and productivity.

(*fig.12*) **95.2%** agreed ambience and colors affect workspace experience. It suggests that **visual design influences mood, focus and creativity**. Employees were to choose from different color palette schemes and most preferred monochrome color schemes especially white/ cream tones and some vibrant colors like blue, green and yellow rather than dark or overbearing colors.

(*fig.13*) **95.7%** agreed green spaces improve health and productivity. It shows **importance of biophilia in workplace design**. This helps promote well-being and reduce stress and fatigue.

(*fig.14*) A **clear majority** of respondents indicated that recreational areas like a library, meditation room, or gym are important in workplaces. This suggests a strong trend toward **corporate wellness and facility provision** in the office environment, with most respondents having access to amenities designed for well-being and breaks.

The results reveal high consensus among participants in the identification of major factors influencing workplace quality. Nearly all participants emphasized having the flexibility in the office layout and furniture, referencing its contribution toward enhanced comfort, collaboration, and productivity. Similarly, nearly a unanimous majority agreed that color palette and atmosphere play a significant role in workspace experience with a clear penchant for light monochrome tones like cream and white, interposed by invigorating colors like blue, green, and yellow to produce an even and positive environment. In addition, numerous interviewees recognized the impact of green spaces on health and productivity, affirming the vital role played by biophilic design in making employees healthier and more resistant to stress.

5. Data Analysis and Findings

230 respondents from the two surveys combined:

- Demographics of Respondents

- **Gender**: A balanced distribution, with slightly more male participants.
- **Experience**: Majority had **1–5 years of experience**, while a smaller proportion had more than 10 years.
- **Age**: Mostly in the **21–35 years** range, representing a young working population.

- **Preference for Green Spaces:** Majority of employees preferred indoor plants, landscaped areas, or natural design elements in offices and Lack of such features was linked to reports of stress and reduced focus.
- **Lighting Preferences:** Natural lighting was overwhelmingly preferred by users and Respondents exposed mostly to artificial lighting reported higher fatigue as well as lower satisfaction.
- **Furniture Comfort (Chair & Desk):** A huge portion of employees rated their furniture as only "average" in supporting posture. Ergonomic shortcomings were linked to back/neck discomfort and reduced productivity. Employees with adjustable furniture reported less fatigue and greater focus.
- **Stress & Fatigue:** High stress levels were reported in workspaces with poor biophilic and ergonomic elements. Employees in well-designed environments reported less stress and greater energy. Directly linked to both biophilia (natural views, plants, lighting) and ergonomics (comfortable seating, posture support).
- **Overall, Job Satisfaction:** Strong correlation found between workspace quality and overall satisfaction. Chi-square analysis confirmed: office typology has a relationship with connectedness to nature, lighting, and ergonomics.

Thus, Employees perceive wellbeing and productivity as multi-dimensional, influenced by both **environmental –** includes natural lighting, visual connectivity to outdoor environment, green landscape and not just the false green plants **(Biophilia)** and **physical** which includes comfort of table and chair to be specific flexibility in workplace like adaptable furniture **(ergonomics)** factors.

Research Method 2 - Live Case Studies:

- **Office 01, PCMC**

The essence of Landmark Design Group's practice is climate-responsive architecture and sustainable design. The company, founded by the Principal Architect of the firm in 1993, is dedicated to building functional, innovative, and sustainable spaces. The property is gifted with a North-East facing plot and an open grass meadow opposite. The more extensive North-Eastern façade is predominantly open to admit soft daylight, with the South-West façade, under direct and intense radiation, constructed nearly

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opaque with only slim, strategically located openings. The studio is such that it is "unenclosed and fully permeable" for the out-of-doors to be included within the workday.

The ground floor has a tropical garden next to an informal meeting room and atrium where the floor is inlaid with natural ground covers and murum. The studio demonstrates its concern for green technology by housing an Earth-Air Tunnel heat exchanger.



Fig.15. *Entrance + conference room*



Fig.16. *Lobby + waiting area.*



Fig.17. *Natural light from North-East*



Fig.18. *green pockets + open plan layout*

(Source: Author)

- **Office 02, PCMC**

  Enpro has been built as a cutting-edge green building that is concerned with the comfort of employees and reducing dependence on traditional air conditioning and artificial lighting. It has been referred to as one of the few buildings in India to aspire for a Platinum rating under the rigorous LEED v4 protocol. Earth Air Tunnel: This system takes advantage of the earth's stable temperature to pre-cool the air supplied to large volume spaces. The fenestration and layout focus on high-quality indoor environment through the supply of sufficient daylight and views to the outdoors for





Fig.19 & 20. *Integration of biophilia at the lobby + earth air tunnel*



Fig.21. *workstations*



Fig.22. *Director's office*

most occupants. The design incorporates special areas of Indoor Vegetation, including plants in the main building and open office space.

(Source: Author)

- **Office 03, PCMC**
  The architecture of the building responds directly to Pune's humid and hot climate, with an emphasis on passive design to reduce environmental footprint and energy consumption. It received a coveted 5-Star certification. A good 95% of the building floor area is non-air-conditioned, depending only on natural cross-ventilation. The building design results in high daylight penetration (more than 60% of spaces are daylit). Evaporative cooling in the canteen space is obtained through deflecting the westerly wind across fountains in a terraced waterbody. The staggered plan and effective fenestration provide maximum availability of outdoor views and the natural landscape to the occupants.



Fig.23. *Staggered blocks and high thermal mass to keep interior*



Fig.24 & 25. *integration of vegetation water bodies*

(Source: Author)

Key Findings from case-studies:

1. **Biophilia**: Natural elements (plants, views, light) strongly improve focus, reduce stress, and enhance satisfaction. There are indoor plants, Creepers along the hallways and workstations. The lobbies were naturally lit and served as recreational spaces with all the vegetation and atriums/skylights.
2. **Ergonomics**: Comfortable, adjustable furniture is critical for reducing fatigue and improving efficiency. different types of seating according to spaces or activity requirements. seating placed along with movement corridors to pause and rest.
3. **Wellbeing**: Stress and fatigue are minimized in offices with better biophilia + ergonomics.
4. **Productivity**: rises when wellbeing is protected; satisfied employees report higher focus and performance.
5. **No Gender Differences**: Patterns of satisfaction and needs were similar across genders.

6. Discussion

From the demographic profile, most responders were young professionals aged between 21 and 35, suggesting that they were used to improved quality workplace environments. Coupled with responders with experience of one to five years, this could also reflect rising awareness of sustainability, mental well-being, and comfort in workplaces. The relatively balanced gender distribution confirms that ergonomic and biophilic demands are common to all user groups and suggests that the pleasure and discomfort patterns were not gender specific.

Based on the survey results, individuals widely prefer nature elements in workplace environments, such as indoor plants, landscaped environments, and natural light. These findings are consistent with earlier studies that have shown biophilic environments enhance mood stability, attention, and psychological recovery. Most respondents wanted more natural lighting compared to artificial light and ranked this as a significant factor. Employees who had the most exposure to artificial lighting reported greater fatigue and visual discomfort, which is consistent with studies that indicate sunshine exposure enhances circadian rhythm regulation and reduces eye strain.

Another significant factor which has been shown to impact job satisfaction is ergonomics. Respondents who were provided with adjustable and posture-friendly furniture experienced much less fatigue and better levels of concentration even though most respondents rated their furniture as "average." The results confirm that musculoskeletal discomfort and decreased productivity are correlated with poor ergonomic conditions, particularly in workstations and chairs. This study supports global ergonomic standards that emphasize task-suitable design, adaptability, and body support for the health of employees.

Levels of stress and fatigue uncovered the interaction among biophilia, ergonomics, and health. Respondents in offices with ergonomically set up spaces and built-in biophilic elements often reported themselves as less stressed and more invigorated.

These survey findings were then corroborated within actual architectural practices by the live case studies, namely Landmark Design Group, Enpro Industries, and PMRDA Office. All three buildings provided a model for how ergonomics and biophilic concepts could be combined within green design paradigms. In each case, it was found that visual connections to nature, daylighting, and open space all contributed meaningfully to improved mental health and productivity.

A working environment that both facilitates physiological comfort (with ergonomics) and psychological renewal (with biophilia) offers the ideal setting for top performance, imagination, and retention.

7. Conclusion

Consequently, the research shows that the physical properties of office spaces are highly related to employees' well-being and performance. Characteristics that include biophilic design, e.g., daylight, plants, and nature views, in combination with ergonomic solutions such as adjustable seating and optimized office planning, are core to the creation of healthy and productive workspaces.

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The research presents tangible evidence that workers placed in environments enriched by these factors feel significantly less stress and fatigue, enhanced focus, and more job satisfaction. The implications for organizations and designers are clear: prioritizing biophilic design and ergonomic principles should be considered not only as a design preference but as a strategic decision that directly affects employee performance, retention, and company success. In today's fast-paced and high-pressure work climates, designing offices that provide both physical comfort and psychological restoration is vital.

In summary, the research attests that workplace design has a significant role in shaping employee experiences. By adding natural elements and ergonomic features to office environments, organizations can design spaces that optimize productivity and overall health. This dual emphasis on mental and physical health is critical to sustaining engagement, reducing turnover, and driving future-proof resilient workplaces. Employees like natural plants over artificial, and natural light over artificial tube lights.

Conflicts of Interest: The author declares no conflict of interest.

Declaration of AI assistance: I acknowledge that Artificial Intelligence (AI) tools were used solely for improving sentence structure or language refinement and correcting grammar in limited sections of this paper — specifically, the Abstract, and the Discussion and Conclusion portions.

The conceptualization, data collection, analysis, and interpretation of results were entirely conducted by the author.

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A Detailed Study on How Home Users Perceive What Architects Design

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Abstract: The design of residential architecture significantly shapes the emotional and functional experiences of its occupants, yet a persistent gap often exists between the architect's intended vision and the user's lived reality. While architects may prioritize concepts of form, spatial organization, and aesthetic coherence, residents experience their homes through comfort, familiarity, and emotional resonance. This study investigates this perception–reality gap, with the aim of identifying how architectural design decisions affect occupant well-being, satisfaction, and sense of belonging.

A structured questionnaire survey was disseminated online to a broad and diverse user group, enabling the collection of quantitative data on residents' perceptions of key design variables. These included color and material choices, ventilation and thermal comfort, natural and artificial lighting, privacy and spatial hierarchy, built-to-unbuilt ratios, and overall layout. In addition to recording user preferences, the survey also accounted for demographic variations such as household size, age group, and lifestyle backgrounds, providing a nuanced understanding of how different users perceive and adapt to similar environments.

The responses are analyzed statistically to identify relationships between design factors and user satisfaction, revealing which elements enhance comfort, functionality, and emotional attachment, and which contribute to dissatisfaction or disconnection. By comparing these findings with conventional architectural design intentions, the study highlights significant misalignments, while also identifying areas where design practice and user expectations converge.

The results advocate a user-centric and empathetic approach to design, emphasizing perception-based strategies that prioritize emotional well-being alongside functionality. Ultimately, the study contributes practical insights for architects and designers aimed at creating residential spaces that foster deeper connections between people and their homes.

Keywords: *Residential Architecture; User Perception; Emotional Well-being; Design Evaluation; User-Centric Design*

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1. Introduction

Architecture can either make or break the physical environment as well as the emotional and psychological experiences of the users. A house, especially, is not just a place to live in, but a place of belonging, home, and identity. However, the intentions of architects are not always followed by the lived experience of the residents.

Although architects might focus on the building form, aesthetics, and space, natural illumination, air circulation, color, privacy, and useful designs that impact daily activities, mood, and well-being are important to residents. This disconnection brings out the necessity of perception-based residential design.

The study explores the perceptions of the home users about the architectural elements and the way the perceptions relate to emotional satisfaction, feeling of comfort and mental well-being. Through analyzing the response of the users, based on the survey data, the study will fill in the gap between the architectural vision and the user experience, which will eventually facilitate user-centric and empathetic design approaches.

Aim of the research was to investigate how home users perceive architectural design elements and to evaluate how these perceptions influence emotional responses, functional satisfaction, and overall well-being, with the goal of proposing design strategies that bridge the gap between architectural intent and user experience.

Objectives:

- To analyze how users perceive key residential design elements such as lighting, ventilation, color, spatial layout, privacy, and built–unbuilt relationships.
- To empirically evaluate the impact of these design elements on users' emotional connection, comfort, and functional satisfaction through survey-based statistical analysis.
- To examine the alignment and misalignment between architects' design intentions and the actual lived experiences of home users.
- To propose perception-driven design strategies that enhance user satisfaction, emotional well-being, and spatial efficiency in residential architecture.

2. Literature review:

A thorough review of several academic papers on architectural perception and user experience, allow a detailed insight on how home users perceive what architects design. These papers dwell on emotional attachment, cultural interpretation, sensory experience, quality of life as well as post-occupancy feedback, which play a role in the realization of user-centered residential design. Together, they introduce a heterogeneous but related perspective on the influence of architecture on human actions, fulfillment and meaning in the inhabited spaces. An article by Dodge et al. (2012) creates a holistic structure that connects the aspect of building performance

with the well-being of its occupants. It emphasizes that architectural appraisal should be made to be inclusive of environmental comforts as well as social interaction in order to be able to provide holistic wellness and satisfaction and hence provide a basis of perception-driven researches that relate human emotion and spatial design. Such a holistic view would assist in placing well-being as a core part of architectural results instead of a back-lodged idea. Expanding on this psychological relationship, Channe (2021) views the direct impact of architectural form to the perception and emotional reaction of the user. The paper underlines that well-known spatial rhythms like courtyards create comfort, and intricate geometries can excite or disorient, which proves that a geometrical structure of the design form is an unconscious emotional stimulus. Such an extension of the Dodge et al. construct into the actual space of composition and rhythm of the images is natural. To keep on the discussion on design and human satisfaction, Jacobi and Bjornner (2024) discuss the interpretation and application of quality-of-life principles to housing design by architects. They disclose a mismatch between the design intent and user satisfaction through in-depth interviews and argue that empathy and participatory approaches can help narrow the gap in perceptions and professional ideals. Their opinions make the conclusions made by Channe justified as they demonstrate that emotional comfort and cultural understanding should be balanced with technical and aesthetic goals.

Spence (2020), on his part, develops this point with a multisensory approach, stating that architecture cannot be perceived visually. Comfort and emotional resonance is highly influenced by sound, scent and texture, which echoes the previous results in terms of the importance of complete engagement of sensory experience in the creation of user-centered design. Similarly to the sensory analysis, Brattbakk and Nordahl (2017) develop the study on how the emotional attachment and the aspect of personalization in residential settings enhance the sense of home. They discover that the possibilities of modification, privacy, and daylight provide the sense of belonging and identity and how emotional welfare converts into spatial satisfaction. This is closely related to the idea of Spence that the richness of senses leads to the increased sense of personal connection.

Moving through that of the experiential to the interpretive, Stollmann et al. (2018) talk of architecture as a way of values and perception and reveal that meaning is created by not just the form of a material but the memory and culture. The theoretical reflection of them supplements the empirical findings of Brattbakk by showing the way in which symbolism and interpretation by the user enhance spatial identity. On the same note, Shynu and Suseelan (2023) present a synthesis of studies on visual perception in the urban environment worldwide. They conclude that natural forms, harmony of balance and color produce universally positive emotions supporting the cross-cultural aspects of the perception identified by Stollmann and supporting the universality of the emotion of design aesthetics.

Perkowski et al. (2024) reinforce these theoretical observations with practical evaluation by performing a post-occupancy analysis of a passive residential structure. They also find that although the goals in terms of energy have been achieved, the residents said that they were satisfied with acoustics and flexibility, reminding designers that perceived comfort cannot be substituted with measurements of efficiency alone. Hong et al. (2015) also build on this idea by

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introducing the concept of human-behavior simulation in architectural education, which proves that by understanding how the user moved and interacted, the designer internalized empathy and social awareness as a key requirement toward reaching the human-centered ideal previously mentioned in the literature.

To conclude, getting back to Dodge et al. (2012) and their interdisciplinary approach, it is clear that well-being and perception are closely connected in architectural design. All these works demonstrate that architecture must transform past aesthetic or technical performance to connect with the users at an emotional, cultural, and experienced level so that what is designed by architects really connects with the way people live and feel.

3. Methodology:

This study is quantitative in nature since it aims at exploring the perceptions of the home users towards the architectural elements of design and how these perceptions affect the emotional and functional satisfaction. A questionnaire was developed and sent through Google Forms to get a wide range of participants of various ages, careers, and residential conditions. This approach guaranteed a great accessibility and the possibility to gather credible and similar data on user experiences.

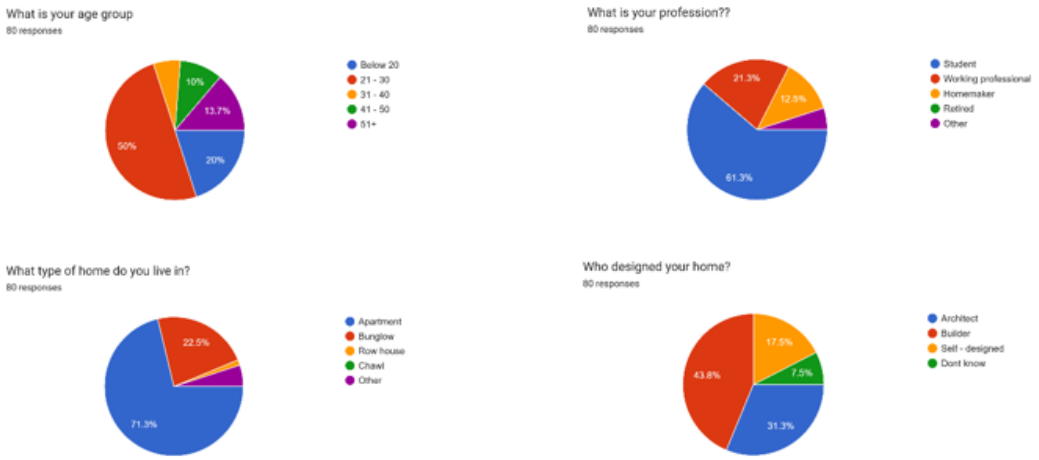
The questionnaire was split into the demographic questions and the perception of the design features, such as lighting (natural and artificial), ventilation, color preferences, privacy, space planning, and the proportion between space built and space unbuilt. The respondents were also requested to provide their insights on emotional attachment towards their houses, their daily mood and well-being, which is affected by the design, and what they would prefer to see in their living rooms. Data coding by statistical analysis to determine repetitions and correlation of design features and user satisfaction. It was done through an empirical assessment of the contribution of particular architectural features to comfort, emotional comfort, and functionality. Through the comparison of these results with the traditional architectural intentions, the present study points out to both the similarities and deviations between design practice and lived experiences.

The adopted methodology is not only useful in the ability to capture user perceptions in quantifiable forms but also highlights the significance of user-centered approach in architectural research. This methodological procedure would mean that the results would also be useful in developing design strategies that would help in closing the gap between the architectural purpose and residential living experience.

4. Data collection and Data analysis:

Section 1: Basic Information & Demographics

Covers respondents' age, occupation, type of housing, and who designed their home.

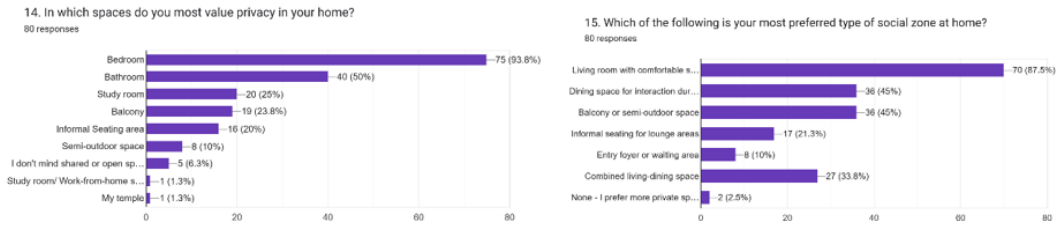


A survey was conducted with 80 respondents to understand residents' perceptions of home design. The majority of participants were in the 21–30 age group, consisting largely of students, followed by working professionals. Most respondents lived in apartments (71.3%), while a smaller proportion resided in independent houses. In terms of design responsibility, the majority of homes were planned by builders, with a smaller share being designed by Architects, and only a few were Self designed.

Section 2: Design features in homes.

Includes responses on lighting, ventilation, color, privacy, noise, layout preferences, aesthetics, emotional connection, and the impact of design on mood and well-being.

A. Privacy -

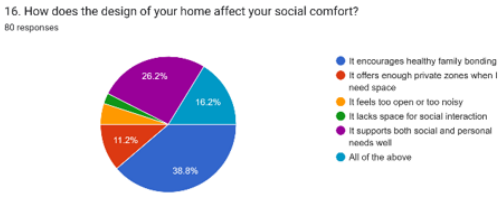


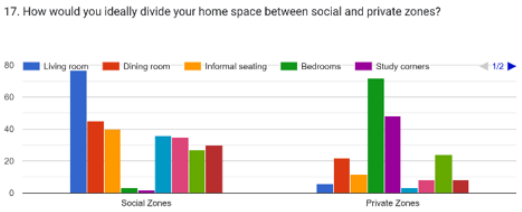
Analysis: Majority of the respondents highlighted the need to have visual and acoustic privacy particularly in their own privacy areas like bedrooms and study rooms. Such areas as living and dining rooms were regarded as more versatile, and openness and visual connection were permissible. This trend demonstrates that the locals instinctively appreciate the equilibrium between seclusion and connection as opposed to complete seclusion.

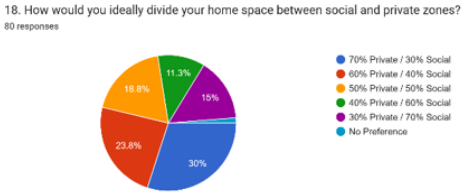
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Architectural Implication: It is the role of architects to set up explicit privacy gradients by zoning space - isolating privacy spaces in relation to circulation routes and other social spaces. Intimacy can be maintained without loss of openness by the use of partial partitions, different ceiling heights and controlled sight lines.

B. Social Interaction & Comfort –



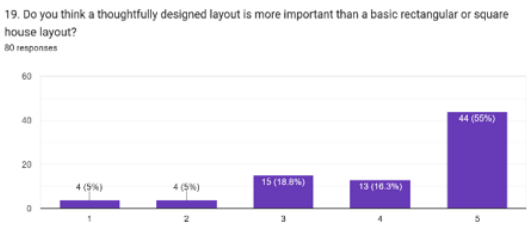


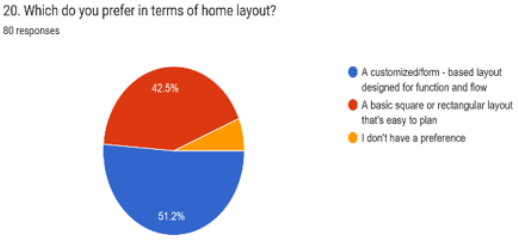


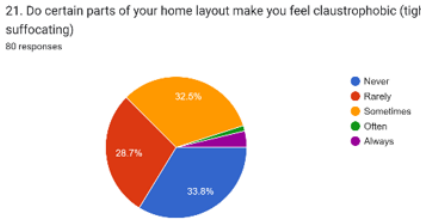
Analysis: Respondents rated their living room and balances as the most comfortable spaces to socialize, as it is the place where they can bond with their families and have informal get-together activities. The answers indicated that individuals prefer semi-open, well-light areas that are appropriate to communicate with each other, but at the same time, leave everyone feeling comfortable. It was observed that the furniture layout and movement between social and privacy spaces had a great impact on their comfort.

Architectural Implication: Adaptive social cores are to be designed by designers and promote communication and visibility as well as provide lightly nuanced boundaries. A smooth transition between collective and personal use can be accomplished with flexible layouts, transitional verandas, and movable systems of furniture.

C. Layout & Spatial Perception -



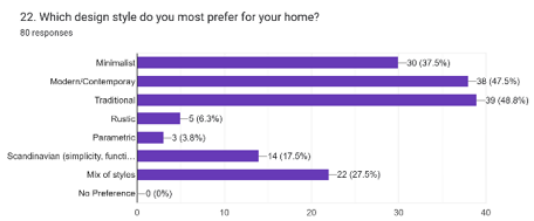


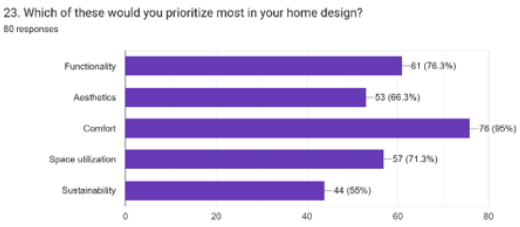


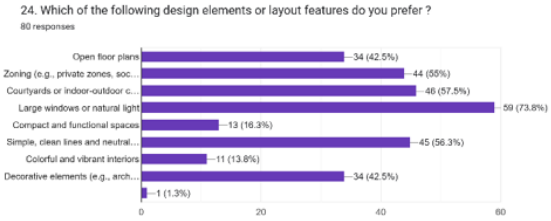
Analysis: The general consensus was overwhelming because a vast majority believed that a considerate layout is better than a pure geometric layout when it comes to the definition of comfort and usability. Open, well-connected layout was preferred by the respondents, as it is associated with spaciousness and the lives of modern people. A less significant group said they were claustrophobic, or uncomfortable in crowded spaces, which could indicate being sensitive to proportion, ventilation, and the distribution of light.

Architectural Implication: The architects are expected to underline spatial hierarchy and proportion instead of strict form. Spatial fatigue may be avoided by ensuring the continuous presence of sightlines, masses to voids, and corridors cross-ventilated, which will enhance the feeling of openness.

D. Design Preferences-





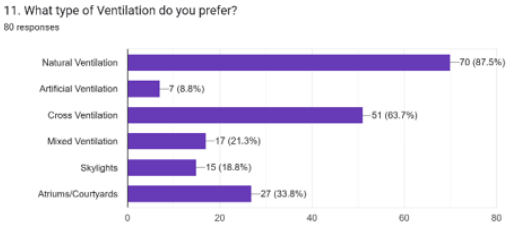


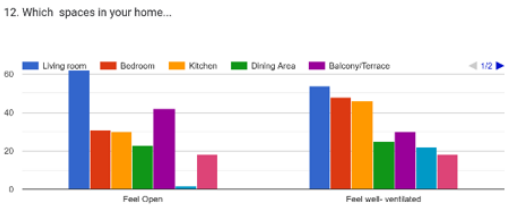
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Analysis: The large majority of the respondents inclined to the modern and minimalistic design aesthetics, equating simplicity to comfort and clearness. Decorative detailing took the back seat to such elements as functionality, natural lightness, and warming of materials. Several were supportive of such aspects as open kitchens, plants, and bigger windows, which demonstrates their aspiration to practicality and biophilic affiliation.

Architectural Implication: Architects ought to incorporate the utilitarian minimalism; a combination of unadulterated geometry and natural finishes that are sensuous. Environmentally friendly materials and natural daylighting designs improve visual serenity and environmental sensitivity.

E. Ventilation –



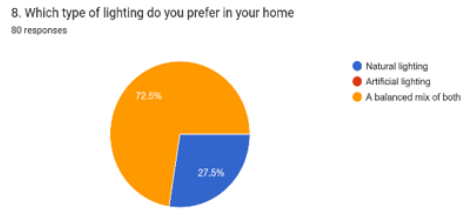


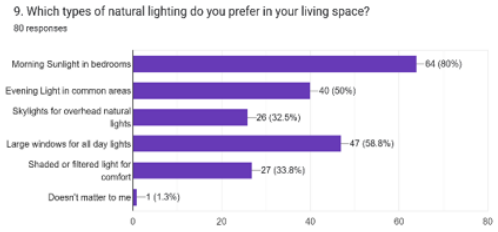
Analysis: Open-plan and cross-ventilation were extremely popular, which supported the significance of airflow in the perceived comfort. Living rooms, balconies and bedrooms were named to be the most open and well-ventilated areas, whereas kitchens and bathrooms were frequently perceived as somewhat clogged or mal-ventilated. This underscores a functional incompleteness in most designed layouts by builder where air circulation is confined to a small area.

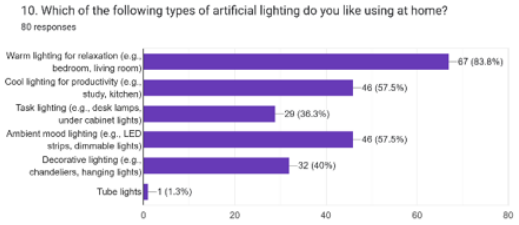
Architectural Implication: Planning The layout planning, strategic arrangement of windows and openings on two sides should all be done to facilitate passive ventilation by architects. Internal air quality can be balanced with the application of courtyard-like empty spaces or even vertical ventilation shafts. Ventilation designs with the use of daylight access can improve not only comfort but also sustainability in very crowded housing setups.

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F. Lighting –



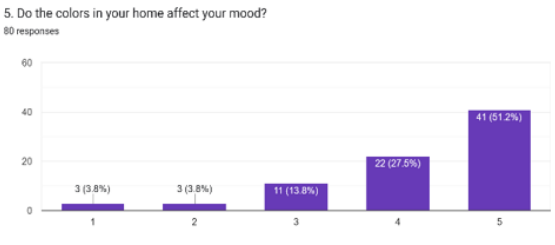


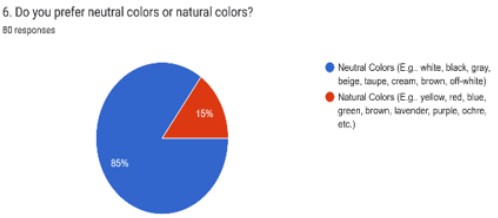


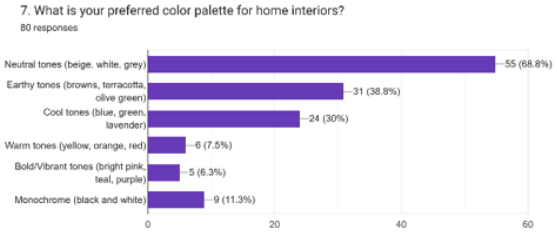
Analysis: Lighting became one of the most important environmental trends that predetermine comfort and aesthetics. Most of them preferred natural light, which elucidates its contribution to positivity and well-being. Big openings, window and skylights were often related with contentment and vibrancy. In the case of artificial lighting, the respondents would like warm white or soft yellow light, claiming it to be relaxing and ambient whereas harsh white lights were not used.

Architectural Implication: Designs must incorporate optimized daylighting by orientation, location of window and reflective surfaces. Artificial lighting should not override nature rhythms: overlay lighting plans with ambient, task, and accent lighting can be used to make people feel comfortable. A change in the direction of circadian lighting design principles would be more in line with the moods and energy states of the users.

G. Colors –





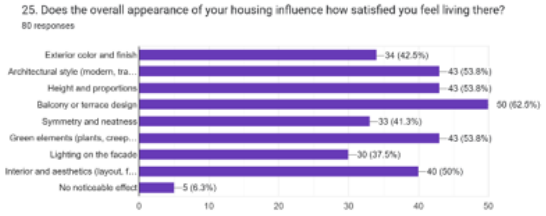


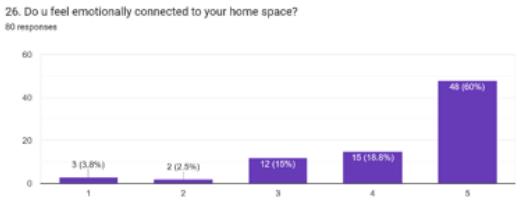
Analysis: Majority of the respondents were of the opinion that colors affect their moods and sense of space. Natural and neutral colors were more popular, especially whites, beiges, and earthy colors, which are calming and spacious in the visual perception. Fewer people stated that they would prefer the pastel or muted colors, which they saw as a fresh and contemporary appearance. The respondents were very few to gravitate towards vibrant or dark colors claiming that the colors tend to make spaces appear small or to be heavy.

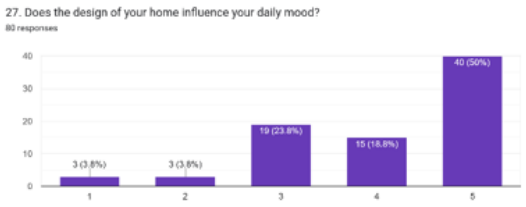
Architectural Implication: The most important feature that should be considered by an architect is a harmonious color scale that provides psychological comfort and visual openness. The inclusion of neutral tones of the base along with mildly accented colors can help to improve emotional health and spatial perception. Color scheme must be in unison with the daylight patterns as well as material textures to ensure unity and responsive interiors.

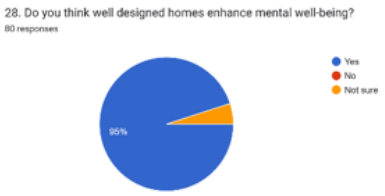
Section 3: Personal Perception.

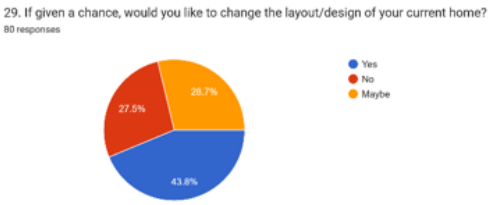
Focuses on whether residents would change aspects of their homes, which areas they would prioritize, and specific improvements they desire.











Analysis: A majority of the people showed a keen interest that the appearance of their home determines their satisfaction and mood of the day. They also related good design with psychological health and emotional stability. Although the majority of interviewees were fond of their homes, they were willing to change the layouts or lighting, which indicated a change of lifestyle.

Architectural Implication: Design is supposed to transcend physical appeal to psychological appeal. Emotional connection and prolonged satisfaction of the residents can be enhanced through personalized detailing, sensory comfort (light, texture, acoustics) and the ability to make future modifications.

5. Discussions:

The desired changes expressed by the residents are usually based on the functional inadequacies and unsatisfaction with the aesthetics in their present dwellings. Most respondents noted that they were highly interested in the enhancement of spatial planning by stating that zoning between residential and social spaces needs improvement, and circulation should be made to eliminate crowded and tight designs. Some of the respondents added that they wished that there were more natural light, cross ventilation, and openings among them because they view them as crucial in making them feel comfortable and healthy. The interior design also underwent transformation, particularly in color palette, furniture styles and use of materials with much desiring livelier yet harmonious interior which represents individual taste. The most common issues raised by respondents residing in older homes or homes designed by builders were inefficient use of space and poor layout which they yearned to change into modern designs that would be more efficient in usage and beauty. Other respondents suggested introducing green features, including indoor plants, terraces, and rooftop gardens to expand the connection with the nature. Although a minor proportion of them expressed their contentment with their existing dwellings, the general mood revealed that the inhabitants were pleased by featuring design modification that can beautify space experience as well as emotional comfort. As these thoughts demonstrate, there is a general trend towards effective, sustainable, and aesthetically enjoyable residential spaces that are responsive to the daily rhythms of modern life.

6. Conclusion:

This study has brought into consideration the fact that residential architecture has a tremendous impact on the emotional health, comfort, and the everyday lives of those who use it. The contrasting discussion of the intentions of architects and lived experiences of residents implies a troubling pattern; design professionals tend to focus more on aesthetics, spatial form, and innovation whereas natural light, ventilation, privacy, and functionality are the fundamental determinants of satisfaction among the residents. The poll of 80 respondents showed that there were consistent preferences of open layouts, cross-ventilation, and clear zoning between social and personal areas, and that there was a need to have spaces that would allow interaction and at the same time provide solitude. The need of the respondents to have more access to daylight, to be in touch with nature via terraces and balconies as well as to be in serene interiors is an indicator of the growing consciousness of the psychological significance of environmental quality in residential houses.

Further, the paper illustrates that the residents view their houses as living things, places that define identity, uphold routines, and add to emotional stability. Such observations demand the movement of designer-based architectural activities to user-based activities, in which empathy, sensorial sensitivity and the sensitivity of context become the core of designing decisions.

Occupant feedback implemented at each phase of design process would help in closing the gap between the professional vision and user experience. Finally, the study promotes functionally efficient, yet emotionally appealing residential settings, which impart health, comfort and a sense of permanence to the present-day housing contexts.

The investigations in the future may build on this base through cross-cultural comparisons, incorporation of smart home technologies, and implementation of biophilic and flexible design principles that are compliant with the upcoming sustainability and well-being tendencies in residential architecture.

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Rethinking Accessibility of Public Toilets: A Case Study of Pune

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Abstract: Public toilets have been a space of intimate and public encounter between architecture and users for many years. In fast-developing Indian cities such as Pune, access to clean and safe sanitation is serious problem. Marginalized sections of society, including women, elderly, the disabled, caregivers, and transgenders, cannot utilize these facilities efficiently. Despite all the efforts and suggestions included in various missions such as the Swachh Bharat mission and laws like the RPWD Act and the National Building Code, they are the most inadequately addressed issues with respect to accessibility in urban planning and city design as there is a vast gap between what is ideal in the way of design standards and what is existing on the ground. Problems like inadequate ramps, narrow doorways, lack of tactile or Braille signs, inappropriateness for women, and lack of gender-neutral or family friendly toilets indicate that accessibility in sanitation is an afterthought rather than a design consideration. This research takes Pune (public toilets of Pashan, Baner, Aundh) as a case study to rethink accessibility in the architecture of public toilets through a threefold approach. First, a systematic site audit of existing public toilets will be conducted using national and international benchmarks, including the RPWD Act, NBC Part 9, Swachh Bharat Guidelines, ISO 21542:2021, and Smart City sanitation standards. Second, the audit documents access routes, fixtures, hygiene, safety, and inclusivity, creating a condition report and compliance gap analysis. Third, a user centered evaluation through semi-structured interviews with diverse stakeholders such as disabled users, elderly persons, women, caregivers, and transgender communities has captured the lived barriers of using public toilets. The study maps spatial inequalities (functional vs. non-functional units, toilet deserts) and identifies red flag zones requiring urgent interventions. Together, these methods have generated a comprehensive understanding of both the infrastructural shortcomings and the lived experiences of users. By integrating technical audits with human-centered insights the aim is to recommend a standard design of the public toilets that can be recommended throughout various zones and also recommend policy and guidelines for execution that are evidence based and can be useful to government official to outline architectural design modifications/ interventions that will enhance accessibility, safety, inclusivity and dignity for all citizens.

Keywords: Public toilets; Accessibility; Universal design; Inclusive architecture; design and guidelines recommendation

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1. Introduction

Public toilets are critical to dignity and inclusivity in cities, yet they remain among the most neglected aspects of urban infrastructure. In India, despite initiatives like the Swachh Bharat Mission, the Rights of Persons with Disabilities (RPWD) Act, and the National Building Code, public toilets often lack basic accessibility features such as ramps, wide doorways, grab bars, tactile signage, and gender-neutral options. As a result, marginalized groups including women, the elderly, persons with disabilities, caregivers, and transgender communities face exclusion and indignity in everyday sanitation practices. This study addresses that gap through a case study of public toilets in Pune's Pashan, Baner, and Aundh areas. Combining audits against national and international standards with user-centered interviews, the research highlights compliance gaps, maps "toilet deserts," and captures lived barriers. The findings aim to inform evidence-based design and policy recommendations that promote accessibility, safety, and dignity for all.

2. Literature review

3.1 Defining accessibility in urban infrastructure

Sanitation has been acknowledged as an important right that is critical to the fair cities. Public toilets satisfy the basic needs and ensure movement, integration and dignity. Duong (2021) locates the toilet in macro (policy), meso (neighborhood access), and micro (safety and cleanliness) levels and underlines the importance of their interaction in the urban design (p. 87). Lewkowitz and Gilliland (2024) draw attention to the UN Human Right to Water and Sanitation and emphasize on availability, accessibility, affordability, quality, safety, privacy, and dignity (p. 288). They promote gender supportive facilities, where signage and facilities should cater to both genders. Inadequate safe and inclusive toilets limit access to the normal life in the city, particularly to the women, gender diversities, elders, and disabled individuals, and accessibility is an essential policy and planning right in the urban area (p. 285).

3.2 Public toilets as urban infrastructure

Public toilets are important urban facilities that influence equity and the general experience in the city. Duong (2021) points out that current toilets are intro-verted objects that fail to interact with their environment and their failure to plan makes them uncomfortable, socially isolated (p. 5, 65). Poor access in high-density cities such as Dhaka encourages unsafe sanitation, which deteriorates the health of people. By considering toilets as infrastructure connected to transport centers, markets, parks, and walks, one can transform them into valuable and exciting communal spaces and make them a community and activity hub (Duong, 2021, p. 5). The concept is part of the sustainable, inclusive urban vision since such an integrated approach will be more accessible, safer, dignified, and socially engaged to all urban dwellers.

3.3 Architecture and urban design of public toilets

Historically, the architects have approached the topic of a public restroom as a utility area and thus tend to design them in a manner that relates to the minimum code standards and the number

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of fixtures, instead of a way to integrate into the life of a city and become part of it (Duong, 2021, p. 65). Duong calls upon repositioning toilets as central, layered spaces that promote social interaction, community engagement and inclusion, suggesting placing toilets at the center of social activity and not in the background and appropriating them with features such as lighting, circulation and social programming to make them worthy of being a valuable public asset (Duong, 2021, p. vii). These forms of innovation transform toilets into stigmatized, underutilized amenities to colorful elements of interacting urban areas and sustaining the life of the people.

3.5 Public health and sanitation concerns

The communal lavatories are essential to the city hygiene, which determines the level of hygiene and infection especially in crowded areas with low standards of sanitation. Hossain et al. (2017) found out that insufficient toilets lead to increased defecation and low satisfaction of the users with the toilet due to hygiene issues. Duong (2021) reveals that toilets are intimate zones, which are significant to mobility and health, particularly to vulnerable groups. Lewkowitz and Gilliland (2024) refer to the fact that the mobility and dignity of women, trans, and gender nonconforming individuals are restricted by the lack of inaccessible and unsafe toilets, which recognizes sanitation as a social determinant of health and equity in urban centers.

3.6 Policy, governance and management framework

Treatment of public toilets has traditionally been considered secondary infrastructure, where the policy of providing public sanitation has put most of the burden on semi-privatized institutions such as cafes at the expense of those unable to afford them (Duong, 2021). Good sanitation cannot be achieved without proper planning, finance and control. According to Lewkowitz and Gilliland (2024), the state responsibility in the UN Human Right of Water and Sanitation framework comprises of availability, accessibility, affordability, quality, safety, privacy and dignity. In such cities as Dhaka, the lack of attention leads to dirty toilets and demand (Hossain et al., 2017). Duong (2021) urges people to see the value of the public toilets as an important urban element instead of a hidden one, whereas Lewkowitz and Gilliland (2024) emphasize on inclusive policies and the need to overcome gender-specific obstacles. Sanitation therefore is a civic issue that is critical in ensuring that urban development is just.

3.8 Gaps and emerging directions in literature

Studies reveal that there are various loopholes in the structure and policy of the public toilets. One, the sanitation planning lacks a connection with the gender-inclusive design, and the needs of women, trans, and non-binary individuals are not fulfilled (Lewkowitz and Gilliland, 2024). Second, toilets have become more of a technical checklist, instead of a useful civic space that invigorates urban spaces (Duong, 2021). Third, there are poor maintenance and governance, where most of the toilets are not properly maintained and are in poor conditions (Hossain et al., 2017). Lastly, the cultural stigma is one of the biggest obstacles to access and inclusion, and participatory and inclusive design solutions will help in the efforts to overcome social and cultural barriers.

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3.9 Benchmark practices and case studies

Swachh Bharat Mission (SBM) provides guidelines of household, community, and public toilets, with the focus on operational and technical performance. It obliges seat-to-user ratio of 1: 35 men, 25 women and urinal facilities, where toilets should be available within 500 meters in residential and 1 km in business areas. Examples of hygiene needs are lighting, anti-slip flooring, disposal of menstrual wastes and skilled employees. According to the ISO/NBC standards of accessibility, one accessible toilet of each gender block should be provided close to the main entrances. They are of two kinds: Type A (2.2m x 2.3m), which can be transferred laterally on both sides and Type B (1.7m x 2.2m) which can be transferred on one side. The maneuvering areas in both should be provided, the floors covered with non-slip, the signage should be in tactile and Braille (below 1.5 m high), and the wheelchair should be clear at least 2.25 m2. A building should have at least one toilet per floor, and two in case there are more than 20 WCs. These standards make it universal and safe to all users.

TABLE 1: Showing the necessary dimensions required for the toilet

USER (m)	LENGTH (m)	BREDTH (m)	DEPTH (m)
50	5.0	2.0	1.0–1.24
100	7.5	2.65	1.0–1.24
150	10.0	3.0	1.0–1.24
200	12.0	3.3	1.0–1.24
300	15.0	4.0	1.0–1.24

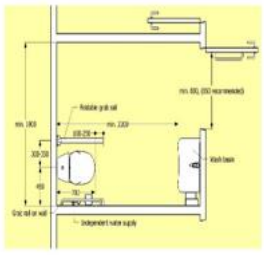


Figure 1. Eg of appropriate dimensions

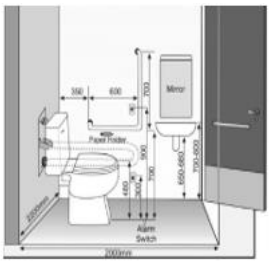


Figure 2. Dim in section

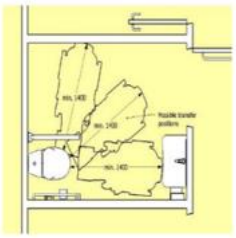


Figure 3. Room transfers options



Figure 4. A detailed overview

3.10 Case studies

Another important development in designing a public restroom in India is the Light Box by Rohan Chavan in Mumbai, which revisits the concept of sanitation as both civic and aesthetic component. The building is designed on the tree that is already there; it also consists of four toilets exclusively for female users, a nursing area, and a disabled and senior toilet. It is characterized by its translucent polycarbonate panels which diffuse the sunlight providing privacy and psychological safety. The design is more focused on visibility, dignity, and safety, which is backed by sustainable materials such as mild steel frames and Kota stone floors. Passive surveillance and community involvement can be achieved with landscaping around the restroom, areas to rest, a gallery, and social facilities. The initiative disperses the 19 th century

stigma, which advocates gender-sensitive cities, which integrate functionality with humanity, with public toilets and civic assets instead of utilitarian requirements.



Figure 5. The lightbox



Figure 6. FAÇADE VIEW



Figure 7. SEATING INSIDE



Figure 8. PWD TOILETS

She toilets Hyderabad Initiated by the Greater Hyderabad Municipal Corporation (GHMC) to supply automated self-cleaning toilets to women only to combat the urban sanitation inequality and security. These are solar powered, modular flushes, sanitary product dispensers as well as CCTV to improve security and hygiene. The project will be located in transit hubs, markets, and bus terminals and will focus on efficiency, safety, and integration into the smart city. It provides a low-maintenance and scalable model of gender-sensitive urban sanitation infrastructure (GHMC, 2018; Sridharan, 2019; Patel and Bansal, 2021).

4. Methodology

The research methodology used was a three-level approach.

The first level was concerned with gathering and analyzing current national sanitation standards and guidelines, such as those described by Swachh Bharat Mission, the Persons with Disabilities (PWD) Act, and other policy framework documents. It also involved a lot of case study analysis as well.

The second level involved fieldwork, with on-site visits and interviews with both users of toilets and government administrators in order to grasp ground-level realities as well as user experience.

Stage three was a site study where the then existing public toilet facilities were comprehensively recorded and analyzed against the identified standards in stage one.

The study focused on three major areas Pashan, Aundh, and Baner chosen to typify various urban typologies: a historic gaothan settlement, a better developed and improved neighborhood, and a transitional area that shows the characteristics of both. The typological diversity enabled a comparative examination of infrastructural deficits and user experiences within contrasting urban environments.

4.1 Semi-structured interviews.

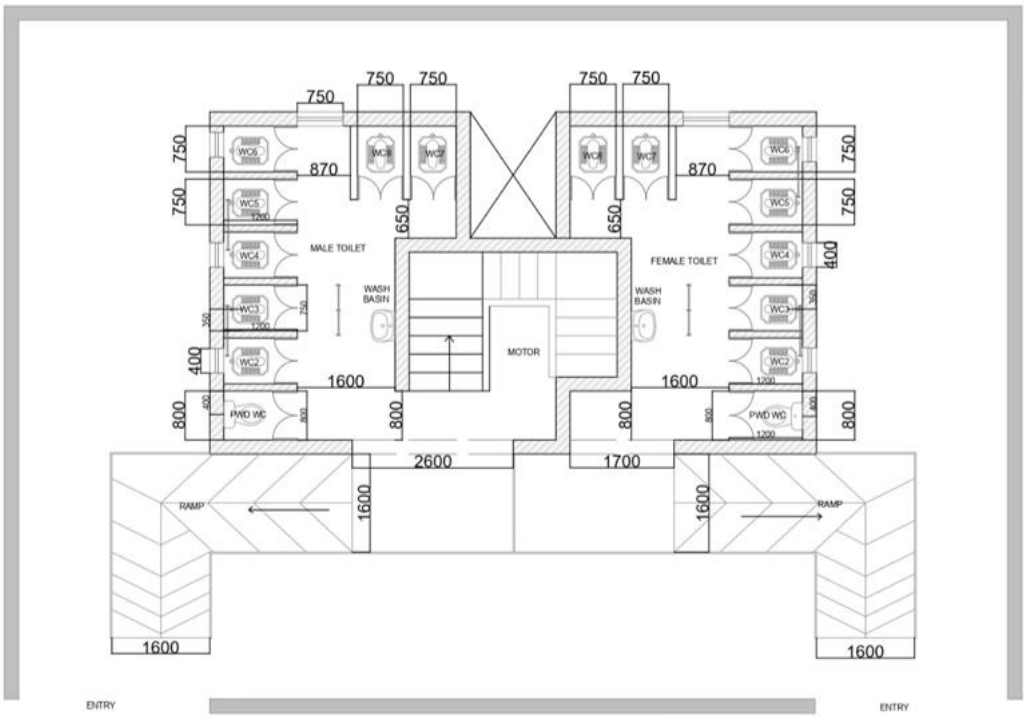
Semi-structured interviews with various users such as persons with disabilities, the elderly, women (particularly menstruating or pregnant) and caregivers were the second phase of the

research. The interviews were conducted based on fears among the users, awkwardness, duration in using the toilets, features which are missing and cultural issues such as privacy and cleanliness. The information was gathered using audio recordings, accessibility mapping, during which the user demonstrated the problem and scenario discussions (e.g., the use of wheelchairs). This qualitative methodology was highly insightful and supplemented technical standards and demonstrated accessibility barriers in the real world.

4.2 Site audit and documentation

The third step of the methodology was site study and analysis using space to determine areas of non-compliance and existence of toilet deserts, which were regions with a deficiency or lack of adequate or ready toilet infrastructure. This was done through drawings which were measured, standardized checklists as well as systematic photographic records. An existing site map of the available public toilet at Pashan was created to record dimensions, layout and spatial content and compared to national technical and accessibility standards set during the first phase. The evidence in photographs consisted of physical states, circulation, signs, access characteristics and neatness. This information allowed evaluating the observance, revealing the absence of standards, determining the main design shortcomings and inadequacy of the infrastructure, as well as providing an opportunity to compare the standards of policies with the situation on the ground.

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PLAN 1: Plan showing the existing toilets

The following photographs show the defects talked about in the previous paragraph



Figure 9. Public toilet in Pashan



Figure 10. Public toilet in Aundh



Figure 11. Interviews with the local



Figure 12. toilet for the disabled



Figure 13. less ventilation and light



Figure 14. leaked fixtures



Figure 15. Slippery tiles



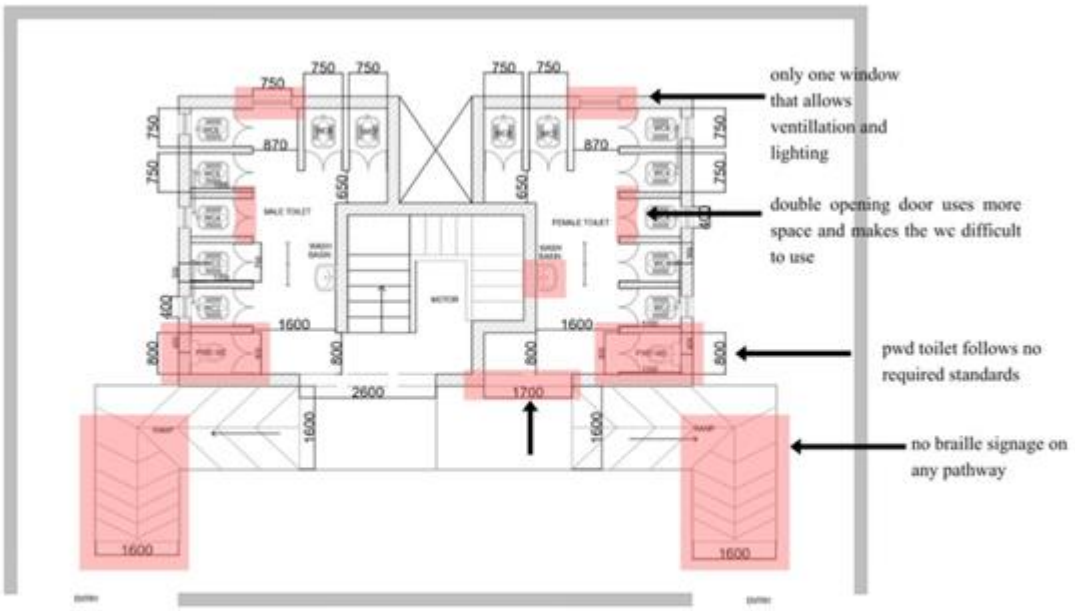
Figure 16. LOCKED PWD WASHROOMS



Figure 17. no privacy

5. Observation / Analysis

The site research and the user interview indicated that there are major problems in the existing public toilets such as poor sanitation, safety, and unavailability and privacy. The unsanitary conditions, lack of lighting and inappropriate ventilation, and absence of safety features, especially during the dark, were reported by the users. Women complained of insufficient sanitary disposal conditions and protection facilities and thereby, many of them do not use public toilets during their menstrual days. The disabled had to deal with broken locks, lack of ramps, inappropriate space, and absence of other safety facilities like grab bars, which meant that people could not access certain areas. Care givers were having trouble with tiny and under furnished stalls without baby changing stations. There was a wide difference between policy standards and ground conditions in the infrastructure which was frequently non-standard, overcrowded and in poor condition. The necessity to standardize the design, enhance the maintenance and inclusive, accessible infrastructure is an urgent concern**.**



PLAN 2: Plan showing the problem areas of the existing toilets

6. Design interventions

The locations of the restrooms representing different locations within distinct urban typologies did not seem to affect the results of analysis on the at the analyzed restrooms, which could be alarming when considering the standards and usability of basic sanitation assets. These challenges could be corrected through various design interventions made at any material, construction, or planning level to enhance functionality, hygiene, safety and inclusivity of public restrooms

6.1. Flooring & Water Management

Utilize non-slip, porous concrete tiles to diminish slipping risk.

Incorporate an underground tank storm-cover drain to divert unneeded water.

Reuse collected water for toilet flushing to effectively manage water sustainably.

6.2. Space Optimization

Substitute traditional swing doors with side shutters in order to maximize area and improve *accessibility.*

6.3. Safety, Surveillance & Maintenance

Add outside CCTV cameras for safety.

Provide both male and female attendants for management and maintenance (also employing someone).

Implement a system for including alarms or timers to initiate cleaning after set duration intervals.

6.4. Natural Light & Ventilation

Install a polycarbonate sheet roof which will allow sunlight and act as a natural disinfectant.

Ensure steel mesh at upper wall perimeter to help with cross-ventilation and minimize odor.

6.5. Waste Management & Hygiene

Install foot-activated sanitary bins in every stall.

Bins must be heavy duty, easy to clean, and regularly maintained.

6.6. Enhanced Fixtures and Water Conservation

Employ suction-based water closets to optimize water efficiency.

Install automated waste removal systems for efficient use of the toilets.

6.7. Access and Inclusivity

Install Braille signage on interior walls and ramps, for the use of persons with visual impairments.

Ensure PWD washrooms meet accessibility dimensions and standards.

Install grab bars and handles for elderly adults.

Install seating areas and stop off points with plants, for women to leave children while they use a toilet in a way that is reasonably safe.

6.8. Cultural and Functional Flexibility

Make an equal number of Indian-style toilets and Western toilets for the benefit of user preference.

While these interventions focus on improving hygiene, safety, and accessibility and comfort for users, they must also comply with national standards on sanitation and accessibility

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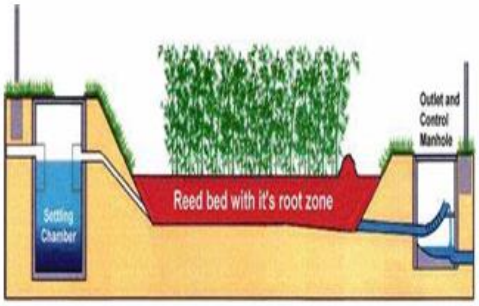


Figure 18. Root zone system



Figure 19. water drain tiles



Figure 20. porous concrete

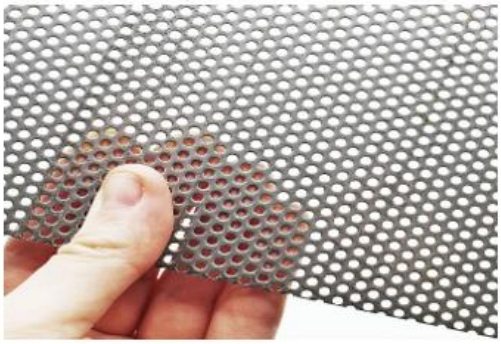


Figure 21. Steel mesh for ventilation



Figure 22. Polycarbonate sheet for maximum light



Figure 23. Support bars for elderly and disabled

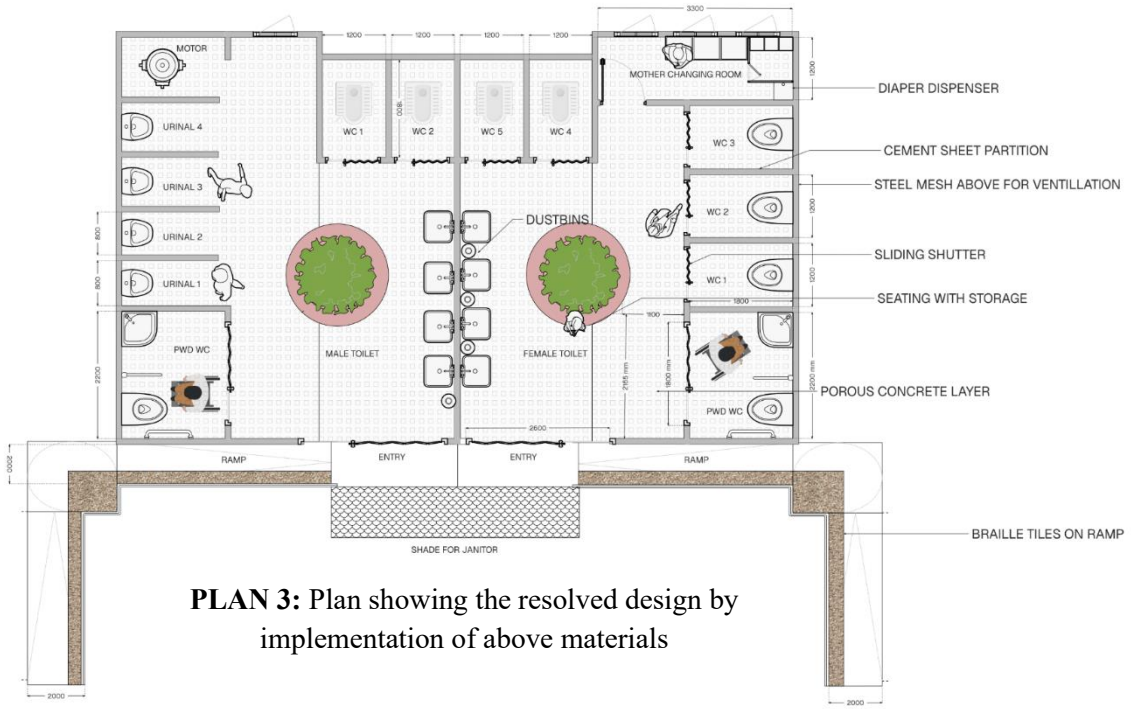


Figure 24. Braille system on ramps



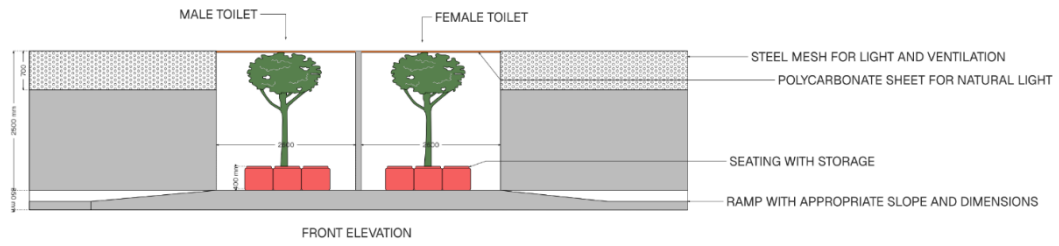
Figure 25. Pause point inside the toilet

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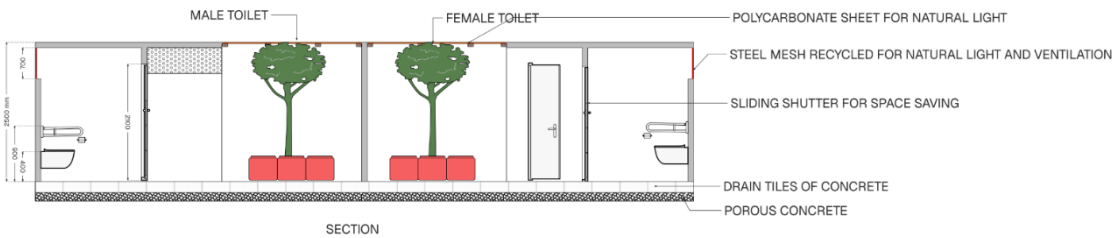


PLAN 3: Plan showing the resolved design by implementation of above materials

The above design has been developed with reference to existing public toilet models to draw a comparison, demonstrating that even minor interventions such as thoughtful material selection, design modifications, and the integration of meaningful features can lead to significant improvements in functionality and user experience.



PLAN 4: Sections and elevations of the above plan



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7.Conclusion

This paper has shown that there is a huge disparity between the national sanitation standards in India and the state of the public toilets in the urban areas. Although, there are such policies as Swachh Bharat Mission, accessibility guidelines, poor cleanliness, absence of safety, inadequate accessibility and gender and disability factors are high in different urban centers. The study was a synthesis of policy analysis and user interviews and fieldwork visits that revealed a systematic lack of translation into positive user experiences. Alternative design solutions such as recycled materials to use in ventilation and modernized fixtures such as robotic toilets are durable, hygienic and cost-effective solutions that support the long-term sustainability. The aim is to ensure that instead of trying to improve urban development by building physical infrastructure, urban progress is evaluated in terms of sanitation infrastructure that would turn the once scorned public toilets into dignified and inclusive urban facilities. This strategy fosters equity, health and human dignity as being central to urban development.

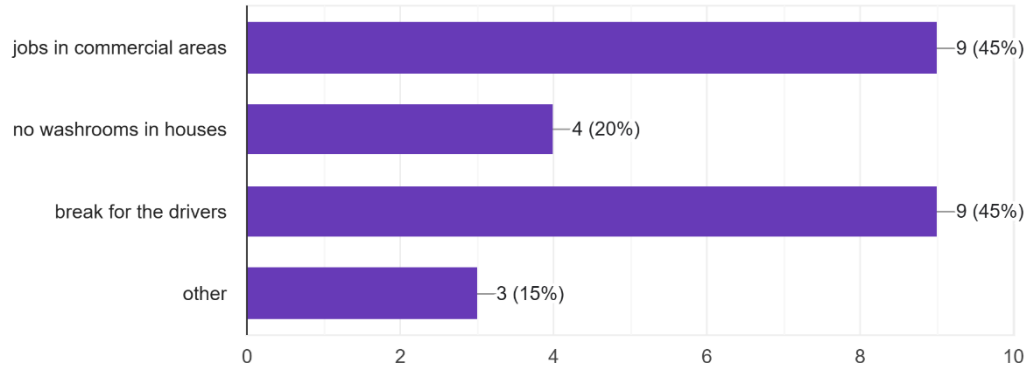
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10. Annexture

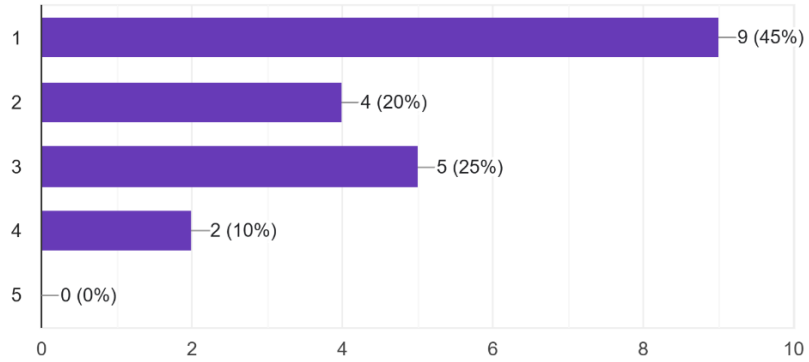
need for the use of this public washroom

20 responses



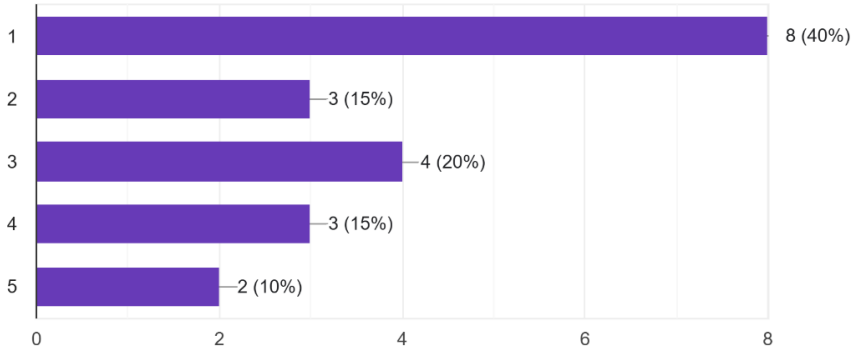
On a scale of 1–5, how would you rate: Cleanliness

20 responses



On a scale of 1–5, how would you rate: Safety

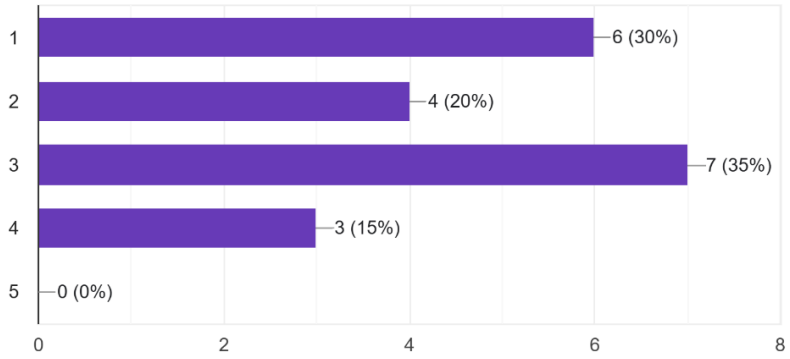
20 responses



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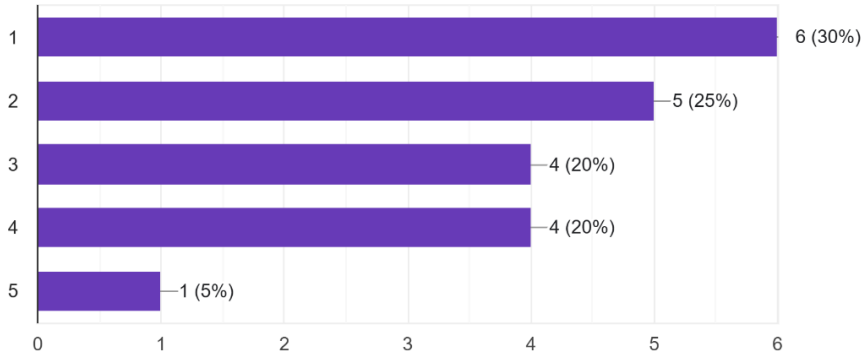
On a scale of 1–5, how would you rate: privacy

20 responses



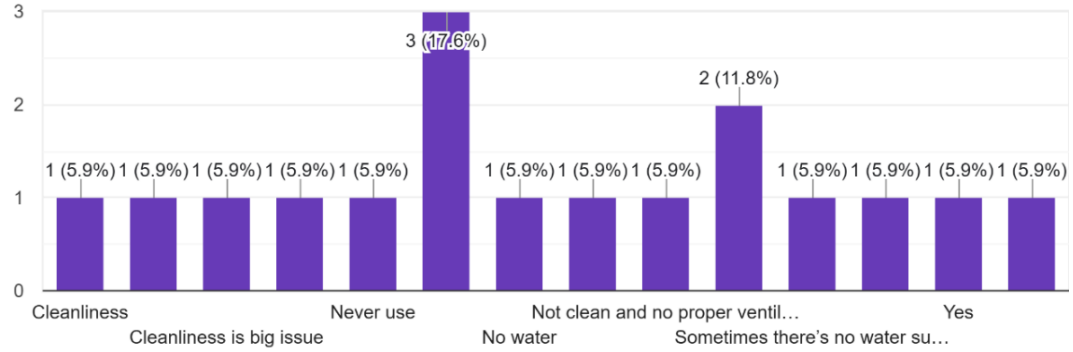
On a scale of 1–5, how would you rate: accessibility

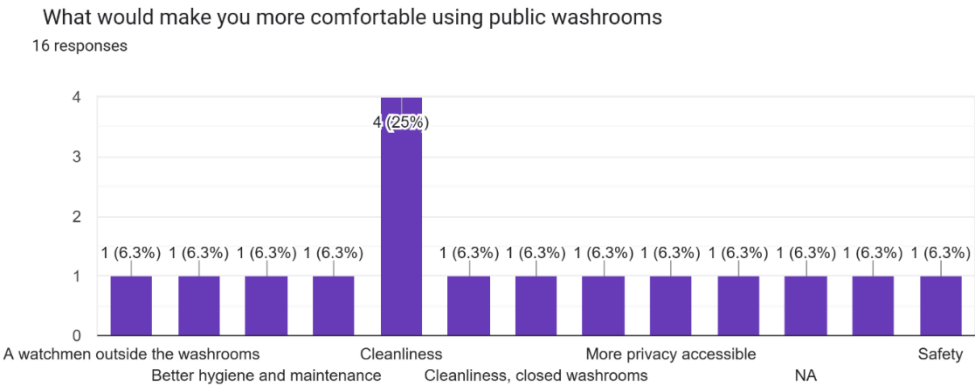
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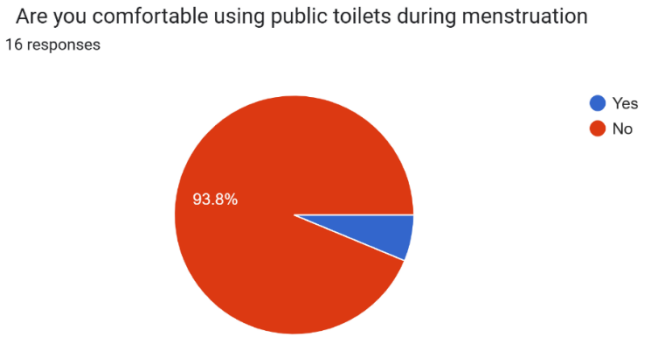


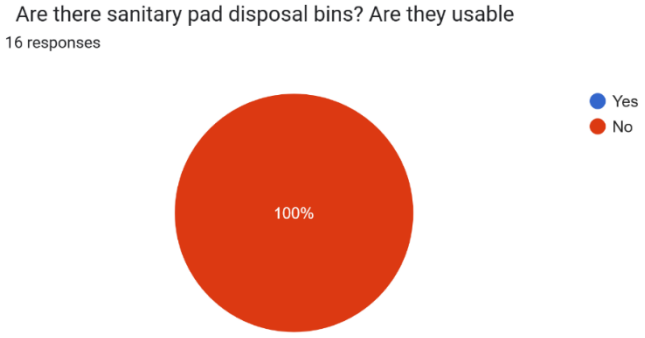
Do you face any problems when using these toilets

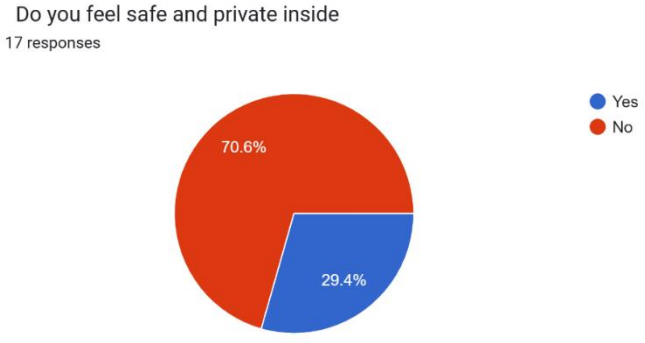
17 responses







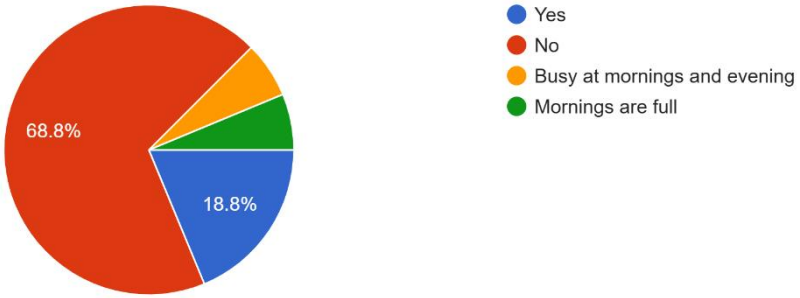




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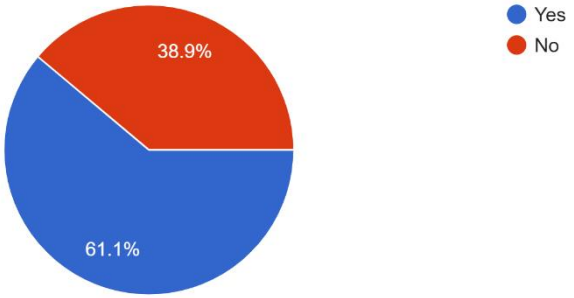
Are the women's toilets available at all times

16 responses



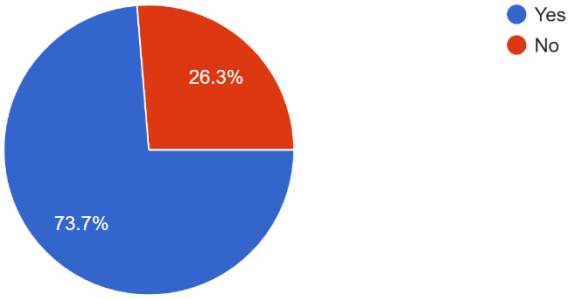
Are the toilets easy to reach from the road or footpath

18 responses



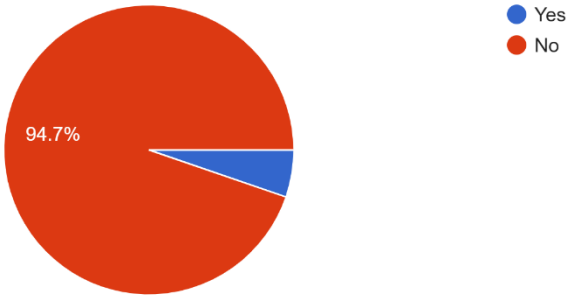
Do you face difficulty squatting, standing, or opening doors

19 responses



Is there any support like grab bars or handles inside

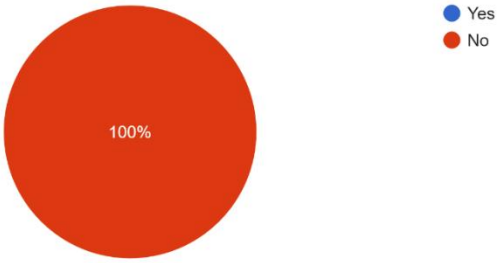
19 responses



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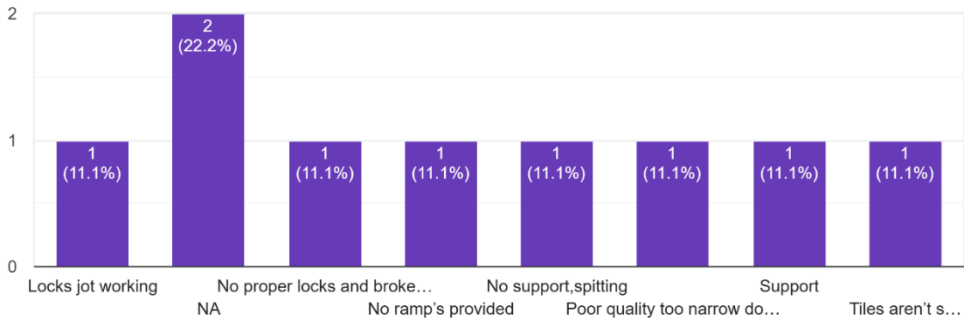
Are you able to access the washroom independently (for disability)

14 responses



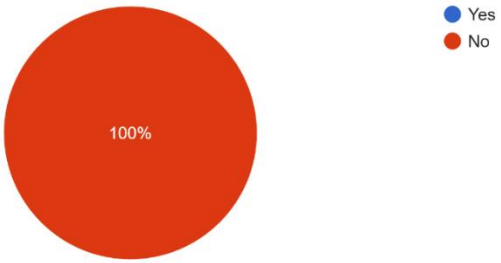
What problems do you face with ramps, doors, or fixtures (disability)

9 responses



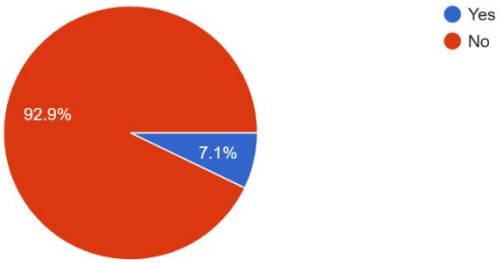
Are there tactile cues or Braille signage to assist you

16 responses



Can you turn your wheelchair inside comfortably

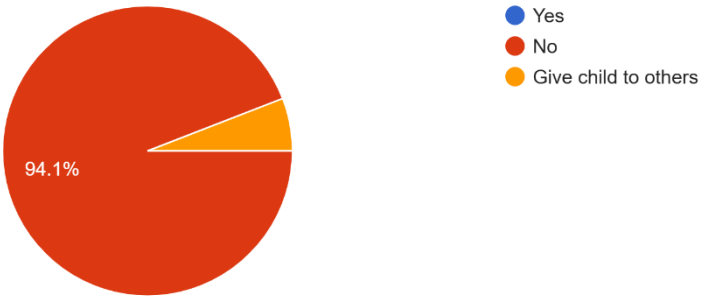
14 responses



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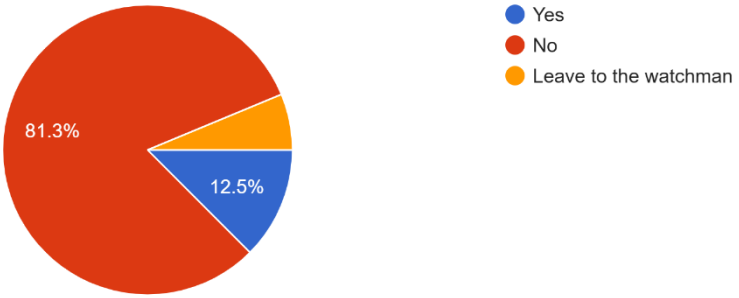
Is there a baby changing station available

17 responses



Can you help your child comfortably inside the stall

16 responses



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Youth Engagement and Disengagement with Urban Open Spaces

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Abstract: Urban public open spaces have long been vital for improving city life by giving people places to relax, play, meet new people, and connect with nature. However, the end user is rapidly evolving, with needs emerging from changing lifestyles, demographic diversity, digital fatigue, and inclusivity concerns. It has been widely observed in literature that today's youth, in particular, are increasingly disengaged from such spaces. With rapidly evolving lifestyles, digital habits, and social expectations, exploring how youth feel, perceive, and interact with urban open spaces becomes critical. Despite their demographic strength and social significance, the preferences of today's youth remain underexplored in urban studies. The central question guiding this study is: How do young adults (18–30) engage and disengage with urban public open spaces, and what factors shape their patterns of use and non-use? To address this question, the research investigates urban open spaces accessible to the public, analyzing physical, perception and preference-based engagements through structured interviews and questionnaire surveys administered to respondents between the ages of 18–30. The study maps both passive and active engagements and explores the reasons behind these patterns of use and non-use. The scope of the study is limited, as sample diversity includes architectural students only. The key finding of the study emphasizes the need to align open space design with the evolving youth engagement to ensure inclusivity, multifunctionality, and continued social relevance, framing them as determinants for future urban open space design.

Keywords: Urban public open spaces; youth engagement; youth disengagement; youth preferences; youth perception; inclusivity

1. Introduction

Urban open spaces have always played a very integral role in the wellbeing of a city. Over time these open spaces have always fulfilled many roles of the changing or evolving needs of various demographic groups. Public spaces are important because they naturally allow for social interaction, personal contemplation, and meaningful encounters with the environment (Tuhkanen et al., 2022) These encounters collectively enhance the psychological, physical, and social well-being of individuals (Zhang et al., 2022), while simultaneously promoting inclusion, tolerance, and a heightened sense of urban belonging (van Aalst & Brands, 2021)

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It becomes very essential to keep a check on the changing trends and their relationship with urban open spaces, for making these open spaces meaningful and relevant with the current times.

Young Adults represent a substantial and dynamic demographic group. They are active, prioritize socializing, are sensitive towards their identity and are influenced by contemporary trends. They frequently use public or quasi-public spaces for socializing, especially since they may lack private spaces of their own (Travlou, 2003). Public space serves as a transitional environment, moving adolescents from playgrounds towards greater independence in choices and decisions, which is crucial for developing personal, social, and civic identity (Kalniņa & Stokmane, 2022). These public areas become crucial for them to meet friends, create their own identities, and engage in activities like 'hanging out' (Travlou, 2003). The ways young people interact with public spaces can indicate broader societal shifts. (Travlou, 2003). Therefore, studying how young adults connect with or disengage from urban open spaces can reveal critical insights for designing spaces that remain meaningful, inclusive, and responsive to current and future needs.

This study aims to investigate how young adults (age 18-30) engage and disengage with urban public open spaces, the reasons for their use and non-use, their preferences and their evolving needs.

The research was carried out in two phases - **Phase 1** involved circulating a Google survey to 50 respondents, and **Phase 2** consisted of conducting structured interviews with a subset of those respondents. The findings reveal a significant shift in how today's youth perceive and prefer urban open spaces, highlighting a noticeable disengagement from traditional urban parks. This signals an urgent need to rethink park design so that these spaces become more meaningful and relevant for contemporary users.

2. Working Definitions:

i. **Youth / Young Adults**: People in the age group of 18 - 30.
ii. **Youth Engagement:** Is the extent to which a youth uses, experiences, connects with urban public open spaces through physical, social, emotional and experiential connections. It reflects both active engagement and passive engagement.
iii. **Youth Disengagement:** The extent to which youth has reduced use, frequency of visit or being absent in urban public open spaces due to lack of physical, social, emotional and experiential connections.

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3. Literature review: The literature review highlighted 4 main themes-

3.1.1 Youth Use, Behavior & Engagement in Parks

Table 1: *Theme wise literature segregation and gaps identified*

Sub-theme	Research Papers	What the Studies Say	Gaps Identified
Youth usage behavior	1. Associations between green space availability and youth's physical activity in urban and rural areas across Germany.(Nigg et al., 2024) 2. Usage behavior and health benefit perception of youth in urban parks: A case study from Qingdao, China(He et al., n.d.)	Youth have distinct needs; use patterns depend on design, maintenance, and environmental comfort.	Underutilization by youth is still poorly understood.
Social engagement	3. How youth are socially engaged in parks: a participatory-approach for understanding youth perceptions and use patterns. (Ziaesaeidi et al., 2020) 4. Socializing in parks: a systematic scoping review to understand how children use parks for social Engagement. (Ziaesaeidi et al., 2025)	Parks support social bonding, identity formation, and community belonging.	Lack of detailed understanding of social activity types and settings.

Identity & risk-reward behavior	1. Deep play, urban space, adolescent place: a multi-sited study of the effects of settings on adolescent risk/reward behavior(Shirtcliff, 1999) 2. Youth in Urban Space: Building Young 3. People's Identity (Europe Goes Local 1 Youth in Urban Space: Building Young People's Identity, n.d.)	Teens navigate spaces differently and use them for identity building and exploration.	Urban design rarely reflects youth identity and spatial practices.
Age-based differences	4. How Do the Young Perceive Urban Parks? A Study on Young Adults' Landscape Preferences and Health Benefits in Urban Parks Based on the Landscape Perception Model(Dai et al., 2022)	Teens and young adults perceive parks differently and need separate design considerations.	Few comparative studies across youth life stages.

3.1.2 Health & Well-being Benefits

Table 2: *Themewise literature segregation and gaps identified*

Sub-theme	**Research Papers**	**What the Studies Say**	**Gaps Identified**
Mental wellbeing	1. Invisible and overlooked: young people's perceptions of managing green spaces for mental wellbeing.(Whitten, 2025) 2. Imagine your perfect park: a qualitative study on adolescents' usage of green spaces, perceived benefits and Preferences.(Sampaio Costa et al., 2024)	Green spaces improve mood, reduce stress; management decisions affect youth sense of belonging.	Limited focus on 16–25 age group; need nuanced mental health measures.
Physical activity	3. Associations between green space	Specific design features	Lack of qualitative insights explaining

	availability and youth's physical activity in urban and rural areas across Germany(Nigg et al., 2024) 4. Characteristics of urban parks associated with park use and physical activity: A review of qualitative research(Mccormack et al., n.d.) 5. Urban Park design and children's physical activity levels: an investigation of design characteristics of green areas and playgrounds(El-Kholy et al., 2022) 6. Associations between park features and adolescent park uses for physical activity (Edwards et al., 2015) 7. A Quantitative Examination of Park Characteristics Related to Park Use and Physical Activity Among Urban Youth (Ries et al., 2009)	influence PA levels; youth PA is globally low.	why designs work or fail.
Perceived health benefits	8. Usage behavior and health benefit perception of youth in urban parks: A case study from Qingdao, China(He et al., n.d.)	Youth value greenery, water, comfort, cleanliness for health benefits.	Few studies integrate perception + actual behavior data.

Source: *Author*

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3.1.3 Park Design, Quality & Features

Table 3: *Themewise literature segregation and gaps identified*

Sub-theme	Research Papers	What the Studies Say	Gaps Identified
Park quality assessments	1. A Quality Index of Parks for Youth (QUINPY): Evaluating urban parks through geographic information systems(Rigolon & Németh, 2018) 2. Exploring the user experience, quality, and provision of urban greenspace: A mixed-method approach (Creed & Carvalho, 2024) 3. Measuring Park Quality for Youth 13-19(August Measuring Park Quality for Youth 13-19 Jelena Kocmaruk Langara Applied Planning Program Major Project, n.d.) 4. Urban parks: Visitors' perceptions versus spatial indicators(Kothencz & Blaschke, 2017)	Tools like QUINPY or GIS-based indicators help measure park quality.	Most tools ignore youth needs or intangible aspects.
Design characteristics	5. User Evaluation of the Urban Park Design Implementation with Participatory Approach Process(Turan et al., 2016) 6. Imagine your perfect park: a qualitative study on adolescents' usage of green spaces, perceived benefits and preferences(Sampaio Costa et al., 2024) 7. How Do the Young	Dynamic sports facilities, multifunctional zones, greenery attract youth.	Lack of long-term evaluation of how needs evolve.

	Perceive Urban Parks? A Study on Young Adults' Landscape Preferences and Health Benefits in Urban Parks+B10 Based on the Landscape Perception Model(Dai et al., 2022) 8. Urban Park design and children's physical activity levels: an investigation of design characteristics of green areas and playgrounds(El-Kholy et al., 2022) 9. Associations between park features and adolescent park uses for physical activity(Edwards et al., 2015)		
Landscape elements & psychology	10. Imagine your perfect park: a qualitative study on adolescents' usage of green spaces, perceived benefits and preferences(Sampaio Costa et al., 2024)	Spatial/facility elements have strongest psychological impact.	Minimal work on youth-specific psychological responses.
Access & distribution	11. Exploring the user experience, quality, and provision of urban greenspace: A mixed-method approach(Creed & Carvalho, 2024) 12. Urban parks: Visitors' perceptions versus spatial indicators(Kothencz & Blaschke, 2017)	Cities often fail to meet accessibility standards; unequal distribution.	Poor mapping of underserved areas and youth mobility patterns.

Source: *Author*

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3.1.4 Inclusion & Accessibility

Table 4: *Themewise literature segregation and gaps identified*

Sub-theme	Research Papers	What the Studies Say	Gaps Identified
Inclusion across ages	1. Inclusive Parks across Ages: Multifunction and Urban Open Space Management for Children, Adolescents, and the Elderly(Sundevall & Jansson, 2020) 2. Quality of urban parks in the perception of city residents with mobility difficulties(Blaszczyk et al., 2020)	Parks must serve children, adolescents, elderly, disabled individuals.	Lack of cross-demographic comparison; mobility barriers poorly addressed.
Exclusion by design/management	3. Invisible and overlooked: young people's perceptions of managing green spaces for mental wellbeing(Whitten, 2025) 4. Measuring Park Quality for Youth 13-19 (August Measuring Park Quality for Youth 13-19 Jelena Kocmaruk Langara Applied Planning Program Major Project, n.d.)	Youth feel spaces are designed mainly for small children.	Need for youth-centered management guidelines.

Source: *Author*

3.2 Inference:

Youth have a very different and unique way of engaging with the urban open spaces, majorly for socializing, creating and exploring their personality, but yet their usage patterns and reasons for non-usage remain underexplored.

Though parks play a vital role in offering physical and mental wellbeing to all age demographics, yet research lacks youth specific evidence explaining how design impacts their interaction and activity.

Youth prefer dynamic, rich in natural features, accessible, vibrant environment, but most tools that assess these needs and requirements fall short to accurately identify them.

Insights are rarely integrated into actual planning processes, and long-term governance impacts are largely unexplored.

Despite the value of youth insights in shaping more responsive public spaces, their voices are seldom reflected in real planning decisions, and the long-term impact of involving them in governance remains largely unexamined.

4.0 Methodology:

The study was conducted in the following three stages.

Stage 01 – Literature Review

Intensive review was conducted to gauge the changing trends and needs of the young adults globally, to trace their evolving preferences in terms of use and non-use of urban public open spaces. This helped to form a survey questionnaire which helped identify their preferences and establish engagement / disengagement.

Stage 02 – Quantitative Survey

A structured questionnaire was administered to 50 architectural students within the age 18 -30 years. The survey collected data on frequency of visits, preference of their places, patterns of engagement and any barriers for their disengagement. This stage provided a broad overview of the relationship between young adults and urban open spaces.

Stage 03 – Qualitative Structured Interviews

Structured interview were conducted with a subset of the survey respondents to gain deeper insights regarding their use and non-use of urban open spaces. These interviews examined experiential qualities, emotional and behavioral connections, and factors influencing youth engagement. It helped validate the findings of qualitative survey enabling a more comprehensive understanding.

5. Data Analysis:

5.1 Quantitative Survey: Comprehensive Summary of Youth Open Space Usage (N = 50)

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Table 5: *Data Analysis*

Category	Variable / Item	Count / Mean	Percentage / Interpretation
1. Basic Details	Age	18–20 (3), 21–23 (14), 24–26 (17), 27–30 (16)	6%, 28%, 34%, 32%
	Gender	Male (14), Female (36)	28%, 72%
	Occupation	Students (42), Working (9), Freelancers (3)	84%, 18%, 6%
	Neighborhood	Urban core (20), Suburban (17), Small town (7), Rural (10)	40%, 34%, 14%, 20%
2. Types of Open Spaces Used	Parks/Gardens	31	62%
	Riverfronts/Lakefronts	29	58%
	Markets/Food Streets	31	62%
	Streets/Crossroads	19	38%
	Cultural precincts/Temples	18	36%
	Playgrounds	10	20%
3. Preferred Open Space (Rank 1)	Riverfronts	~29 votes	Highest
	Hills	~28 votes	High
	Lakefronts	~28 votes	High
	Public parks	~27 votes	Moderate
	Playgrounds	~10 votes	Lowest
4. Continuity of Childhood Spaces	Yes	32	64%
	No	6	12%
	Sometimes / changed	22	44%

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5. Frequency of Use	Daily	-	Very low
	2–3 times/week	-	Low
	Weekly	-	Moderate
	Occasionally	-	Highest
	Rarely/Never	-	Noticeable
6. Duration of Visit	<30 min	6	12%
	30 min–1 hr	22	44%
	1–2 hrs	20	40%
	>2 hrs	2	4%
7. Who They Go With?	Alone	-	28%
	Friends	-	86%
	Family	-	52%
	Partner	-	24%
	Colleagues	-	26%
8. Preferred Time	Evening	-	92%
	Early morning	-	52%
	Late night	-	32%
	Daytime	-	14%
9. Preferred Activities	Socializing	-	82%
	Relax/music	-	54%
	Attend events	-	48%
	Exercise	-	46%
	Quiet reflection	-	42%
	Play sports	-	36%
	Create digital content	-	14%

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10. Motivation Importance (Mean 1–3)	Relax	~2.8	Highest
	Connect with nature	~2.7	High
	Meet friends	~2.3	
	Exercise	~2.2	
	Work/study	~1.6	Lowest
11. Barriers	Lack of time	-	78%
	Poor maintenance	-	52%
	Poor connectivity	-	42%
	Feels unsafe	-	30%
	Uncomfortable climate	-	26%
	Nothing to do	-	24%
	Prefer indoors	-	6%
12. Discouragement Factors (Mean 1–3)	Heat / no shade	~2.3	
	Lack of amenities	~2.6	High
	Poor safety	~2.5	
	Poor cleanliness	~2.7	Highest
	Nothing exciting	~2.1	

Source: *Author*

5.1.1 Inference:

a) The most preferred urban public open spaces were parks and gardens and streets and markets, both at 62%. The second-highest preferences were hills / riverfronts at 58%, followed by temples at 36%.
b) Although youth indicated a preference for parks and gardens, they actually visited spaces with natural scenic value—such as hills, riverfronts, and lakes—more frequently.
c) The most striking finding was the frequency of visits, with "occasional" being the most selected option. The average duration of 30 minutes to 1 hour further highlighted a clear disengagement of youth from urban parks.

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d) Youth prefer going out mainly with their friends, mostly in the evenings, and primarily to socialise, relax, and unwind. Relaxation was rated the highest, indicating a strong need for a break or pause from daily routine. The high rating for connection with nature further suggests an urgent need to escape their mundane lifestyle.
e) While the main barrier identified was lack of time, structured interviews revealed a clearer picture: poor maintenance, crowded conditions, and unhygienic environments emerged as major red flags.

5.2 Qualitative Structured Interviews:

A total of 15 students, who were a subset of earlier questionnaire participated in this structured interview. The interviews aimed to examine and validated the findings from the google survey to obtain accurate reasons of engagement and disengagement.

Table 6: *Data Analysis*

Sr.No.	Question	Answers	Inference
1	Preferred type of urban open space	Hills and Hilltops, Waterfronts (Rivers and Lakes), Temples, Vibrant streets (shopping opportunities, cafes and friends) and markets.	Youngsters prefer natural environments, active and vibrant places.
2	Visit Frequency	Daily to weekly depending on proximity and access.	A strong indication of integrating natural environments into their daily life.
3	Motivations for visiting	Physical exercise (walking, jogging, cycling), socialising with peers, mental peace and enjoying the scenery.	Youth needs both functional and emotional connect from urban open spaces.
4	Preferred physical / design elements in urban parks	Dense vegetation, Water features, cleanliness, good maintenance, photogenic spots, good aesthetics (Instagram worthy)	Youths evaluate the urban open spaces on aesthetic appeal (photogenic spots, maintenance) and sensory richness.
5	Social Expectations	Expect people of same age group (complain about urban parks being dominated by senior citizen age group), moderate crowd size, decent social behaviour, spaces that match their ‘vibe’	Public spaces must have balanced age group distribution and appropriate stimuli to cater to everyone’s needs, should support youth identity, must be safe and decent.
6	Reasons of Disengagement with urban parks	Lack of vibrancy or youth centric activities, limited aesthetic appeal, lack of scenic elements, mismatched crowd and activities (too many elderly people and/or indecent behaviour), poor maintenance and cleanliness issues.	Current urban parks do not match the expectations of today’s youth in terms of vibe, activities, nature, social energy and aesthetic standards.

Source: Author

Table 7: *Data Analysis-Initial Coding*

Interview Response	Initial Code
Preference for hills, hilltops	Scenic landscapes
Preference for riverfronts and lakes	Waterfront environments
Preference for vibrant streets, cafes, markets	Active urban spaces
Visit spaces for walking, jogging, cycling	Physical activity
Visit spaces for socialising	Peer interaction
Visit spaces for mental peace	Relaxation / stress relief
Enjoy scenic beauty	Nature appreciation
Preference for dense vegetation	Natural features
Preference for water features	Water-based landscape
Preference for photogenic places	Instagram-worthy spaces
Good aesthetics and ambience	Aesthetic quality
Expect similar age-group users	Peer presence
Preference for moderate crowd	Comfortable social environment
Need decent behaviour in public spaces	Social safety
Lack of youth-centric activities	Activity mismatch
Lack of scenic elements	Poor experiential quality
Poor maintenance and cleanliness	Maintenance issues
Parks dominated by elderly	Age-group mismatch
Lack of vibrancy	Lack of social energy

Source: *Author*

Table 8: *Category Clustering*

Category	Codes Included
Preferred Natural Environments	Scenic landscapes, waterfront environments, dense vegetation, water features
Social Interaction Needs	Peer interaction, similar age-group presence, moderate crowd
Psychological & Well-being Motivations	Relaxation, mental peace, nature appreciation
Aesthetic & Experiential Qualities	Photogenic spaces, aesthetic quality, scenic beauty
Activity & Functional Expectations	Physical activity, youth-centric activities
Environmental Quality	Cleanliness, maintenance
Social Environment	Social safety, behaviour norms
Disengagement Factors	Activity mismatch, lack of vibrancy, age-group mismatch

Source: *Author*

Table 9: *Theme Development*

Theme	Categories Included
Preference for Nature-Rich Environments	Scenic landscapes, waterfront environments, natural features
Social Interaction and Peer Spaces	Peer interaction, social environment

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Psychological and Well-being Needs	Emotional motivations, mental wellbeing
Experiential and Aesthetic Qualities	Visual aesthetics, experiential qualities
Functional and Activity Expectations	Activity opportunities
Barriers and Disengagement Factors	Environmental barriers, social mismatch

Source: Author

Final Thematic Structure

Responses → Codes → Categories → Themes

Responses → Interview statements
Codes → Scenic spaces, socialising, aesthetics, maintenance issues
Categories → Preferences, motivations, experiential qualities, barriers
Themes →

- Nature-rich environments
- Social interaction spaces
- Well-being needs
- Experiential aesthetics
- Disengagement from conventional parks

5.2.1 Inference:

Youth of today need places that **match their 'vibe'**, spaces where they can **'hangout'** with friends and peers. They look for areas that offer **scenic quality** along with the **presence of water**, where they can sit beside it and **'unwind'** to find some **'peace of mind'**. The place should have a strong **aesthetic appeal**, be **'Instagram worthy' or 'Instagramable'**, allowing them to click and share photos on social media. They often spend **half of their time photographing** and the **rest half 'living in the moment'**.

They also prefer spaces with a **decent crowd with good manners**, small cafés, a **nice ambience**, and areas that are not crowded. The presence of **similar age-group peers**, opportunities for **socialising**, some **scenic value**, and a **vibrant, active** environment make such spaces appealing to them.

6.0 Discussion:

Findings show that while youth value urban open spaces, they are increasingly disengaged due to poor maintenance, lack of vibrancy, safety concerns, and minimal aesthetic appeal. They prefer natural, scenic, and socially active environments—hilltops, waterfronts, and lively streets—over conventional parks. Their motivations focus on relaxation, socializing, and mental well-being, with strong emphasis on aesthetics and "Instagram-worthy" experiences. Current parks often fail to match their desired vibe, age-group dynamics, and experiential needs

All together, the study suggests that conventional urban parks, in their current form, fail to deliver the vibrancy, aesthetic appeal, and emotional engagement young people seek. Instead,

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youth gravitate towards spaces that offer natural beauty, social energy, experiential value, and visual appeal—qualities increasingly central to their lifestyle and mental well-being.

7.0 Conclusion:

Today's youth increasingly desire clean, scenic, multipurpose, and socially vibrant public open places that develop identity, relaxation, mindfulness, and peer interaction. However, typical parks often fail to match these expectations, leading to disengagement at a time when young people are experiencing higher demands, decreased access to green spaces, and rising mental health issues. Despite the well-established benefits of nature engagement, the 18-30 age group remains understudied, with most policies focusing on children or older adults. This diverse cohort requires more detailed, inclusive approaches to park design and management. Future research should involve a broader and more representative youth sample. Cross-city comparisons and investigations into digital habits, safety perceptions, and identity-related needs are essential. Such insights can guide the development of youth-responsive, nature-rich, aesthetically appealing, and well-maintained public spaces that cultivate meaningful engagement and promote long-term well-being.

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