Editors: **Prof. Vineet Shrivastava, Ar. Dwijomala Hanjabam, Ar. Zothanzuala**

Conference Proceedings of The International Conference on Rethinking Built Environment (INCORBE 24)

INCoRBE

School of Fine Arts, Architecture and Fashion Technology
Mizoram University, Tanhril, Aizawl, Mizoram, India - 796004

International Conference Proceedings on

Rethinking Built Environment (INCoRBE 24)

6-8 March, 2024 (Hybrid Mode)

INTERNATIONAL CONFERENCE ON RETHINKING BUILT ENVIRONMENT, INCoRBE 24

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Organized by

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FOREWARD

The Department of Planning and Architecture, Mizoram University adds one more feather to its cap by organizing the first international Conference on" Rethinking Built EnvironmentINCoRBE24". The Northeast region of India, like other regions within the country, possesses a unique and distinctive character that significantly adds to the overall richness of the vibrant cultures of our nation. The Department of Planning & Architecture, a constituent Department of Mizoram University under the School of Fine Arts Architecture and Fashion Technology, which has received official recognition from the Council of Architecture under the Architects Act of 1972 was founded in May 2013. This department provides undergraduate programs in Architecture (B. Arch.). To expand its offerings to include post-graduate and Research programs in the future, the department aims to uphold a standard of excellence in architectural education by fostering strong partnerships with renowned institutions, organizations, and firms that are actively engaged in the industry, as well as other professional bodies.

Architecture and its allied professions are experiencing substantial transformations in reaction to numerous urgent concerns. Addressing climate change is currently the most crucial challenge in the field. The necessary adjustments prompt inquiries on the utilization of material and spatial resources, which, together with growing expectations for social duty and accountability, pose challenges to the ethical and aesthetic principles of the field of architecture. Artificial intelligence's rise threatens traditional ideas of creativity and authorship. Digital design and manufacturing techniques are merging with economic and organizational shifts in the construction sector, disrupting disciplinary boundaries, processes, and traditional architectural models. Is architecture evolving, diversifying, fragmenting, or rooted in a core that enables it to address new challenges? We analyse the current state of the profession and consider its potential evolution and adaptation. We aim to understand the influence architects have on our built environment. Academicians and industry experts will present their expertise and experiences at the conference to improve and critically examine our grasp of future advancements in the built environment. We want to establish a platform for discussion and creativity through presentations, discussions, and debates to advance the subject. The conference explores the current state of design as we set out to determine the ideal characteristics of the built environment of the future.

The generous funding from Mizoram University and knowledge partner institutions and agencies is greatly appreciated. We attribute our success to the outstanding contributions of our colleagues, who served as a source of motivation and made significant strides in the establishment of the present Planning and Architecture Department at Mizoram University. We would like to express our gratitude to the School Dean and Vice-Chancellor, our colleagues, the administrative staff of the department and university, and our committed team for their unwavering support in making this conference a success.

25th February 2024 Prof. Vineet Shrivastava

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प्रो. दिबाकर चंद्र डेका
कुलपति

Prof. Dibakar Chandra Deka
Vice-chancellor

Message from Patron

It gives me immense pleasure to know that the **School of Fine Arts, Architecture and Fashion Technology** of my University is hosting **INCoRBE-2024**, the first international conference on 'Rethinking Built Environment', which is considered a remarkable milestone in the journey of the department's growth. As architectural technology advances rapidly, it is crucial for architecture and design practices to remain up-dated and not be constrained by out-dated methods. Current research and methods are critically needed to address global concerns in the fields of architecture and urban planning. This conference seeks to advance innovative research and facilitates debates to develop new approaches that increase occupants' health, comfort, and productivity within the context of the built environment. The goal of the conference is to raise awareness of contemporary, research and practices that can improve the built environment and make it more livable for people while allowing development to continue unabated. The conference will provide a platform for increased collaboration focused on sharing knowledge, exploring research skills, and introducing new ideas to participants to analyze cutting-edge research in Architecture and related fields. At the end of the day, creative concepts and technically sound frameworks are expected to emerge out of the conference.

I wish a grand success of the conference and a rewarding experience for the participants.

Prof Dibakar Chandra Deka

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Prof. Lalnundanga
Registrar
Mizoram University

REGISTRAR'S MESSAGE

It is my great pleasure to extend a warm welcome to all participants, scholars, and delegates attending the International Conference on Rethinking Built Environment 2024 (INCoRBE'24), organized by the School of Fine Arts, Architecture and Fashion Technology, Mizoram University.

As Registrar, I am delighted to witness the convening of this prestigious conference, which promises to be a hub of intellectual discourse and exchange. The themes of rethinking the built environment is of paramount importance in today's rapidly evolving world, where the need for sustainable, resilient, and inclusive architecture and urban spaces have never been more pronounced. I commend the school for their exemplary efforts in organizing this event and bringing together such a distinguished gathering of experts and thought leaders. I am confident that the discussions and collaborations fostered during this conference will pave the way for transformative change in the field of built environment studies.

On behalf of Mizoram University, I extend my best wishes for a productive and inspiring conference experience. May your deliberations contribute to the advancement of knowledge and the realization of a built environment that is sustainable and equitable for all.

With Best Wishes

Prof. Lalnundanga

Registrar,

Mizoram University

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Message from the Chairman

I am delighted to know that the School of Fine Arts, Architecture and Fashion Technology is hosting the first ever International Conference on Rethinking Built Environment (INCoRBE) during 6-8 March, 2024. The theme of this Conference, Rethinking Built Environment reflects our commitment to develop recent advancement, innovations, collaboration and performing interdisciplinary research to address new challenges in the environment from the academic community. In this Conference, it is a great priviledge to have renowned keynote speakers, panelists and participants who will enrich our understanding of Rethinking Built Environment and inspire us with their expertise. I convey my deep appreciation to the Organizers and offer my good wishes for the success of the International Conference.

Regards

(Prof. Zaithanzauva Pachuau)

Prof. Vineet Shrivastava
Head of Department
Planning and Architecture, Mizoram University

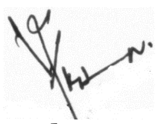
CONVENER’S MESSAGE

For ages, architecture and the built environment have been a primary indicator of a society's level of development. The built environment shapes our daily routines, and it shapes individual and collective identities. It affects an era's resiliency and guarantees its continuation into the future. In the meanwhile, many of these variables also affect the built environment. So, naturally, we must wonder: what and how should the architecture of the future be like? And a more fundamental query: what may this future entail? Would it be predetermined and scripted, indistinct but predetermined? Is this the future we may expect tomorrow, or is there anything else in store? Would it be a world overrun by artificial intelligence and machine learning, or would it be sensitive and contextual like a gendered space? Can it take climate change into account more? Can it bring back sustainable methods that have relevance? The scope of what could happen is huge. The purpose of the International Conference on 'Rethinking Built Environment' INCoRBE’24 is to start thinking about these issues. Learn how our civilization leaves an effect that goes well beyond the tangible. The conference theme is relevant for comprehending society as a whole and architecture specifically, it aims to facilitate discussions on all aspects of architecture, with different related sub-themes established for this purpose.

The exploration of diverse crucial factors within the fields of architecture and urban development is of utmost importance to ascertain their future trajectory. The discovery and expression of individual voices have a pivotal role in elucidating and clarifying long-standing perceptions. Research papers were invited from academicians, professionals, researchers and students on the theme and sub-themes. A tremendous response has been received from all over the country and more than 186 abstracts have been received. The conference themes are well taken by the architecture fraternity and here the book of abstract reflects the same. All conference paper abstracts underwent a thorough blind review process. I appreciate the diligent efforts of our review and publication committee, as well as the authors' meticulous work on their papers.

This opportunity to compile the thinking of so many academicians, scholars and practicing architects has been an immensely enriching experience. With immense pleasure, the book of abstract for the International Conference on “Rethinking Built Environment' INCoRBE24” are presented in the form of this publication.

With Best Wishes



Prof. Vineet Shrivastava

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Ar. Emeline Z. Renthlei Asst. Professor, Mizoram University

With a more than 10 years teaching experience coupled with two years of practical industrial exposure, she brings a rich blend of academic prowess and real-world insights to the table. Completing B.Arch from Sir J.J College of Architecture, Mumbai and M.Sc in Sustainable Buildings from Oxford Brookes University and is currently in pursuit of a Ph.D. at IIT Kharagpur. Her research interests orbit around the critical nexus of sustainable communities, sustainable indicators, and innovative community design, reflecting a deep commitment to fostering environmental stewardship and societal resilience. With a solid foundation in academia and industry, she is poised to make significant contributions in the realm of sustainable development.

Ar. Sylvia Romawizuali Asst. Professor, Mizoram University

Since May 2013, she has been working as an Assistant Professor in the Department of Planning and Architecture at Mizoram University. She is an alumna of JNTU Hyderabad and the University of Nottingham where she completed her master's in theory and design. She also served as VC of the Mizoram Chapter of the IBC, Finance Secretary of the MZU Incubation Steering Committee, member secretary of MZU Alumni Advisory Committee. Actively does professional work and her area of interest lies in the area of heritage conservation and energy efficient buildings.

Dr. Sachin Yadav Asst. Professor, Mizoram University

He is an accomplished professional in the field of architecture and planning, with a strong focus on regional planning and sustainable tourism. He holds a B.Arch degree, a PG degree in Planning, and a PhD in Regional Planning. With expertise in vernacular architecture, his dedication towards preserving and promoting traditional styles and techniques within contemporary contexts. His research interests also extend to policy research, where he explores the intersection of urban development policies and sustainable practices. His work in sustainable tourism underscores his commitment to balancing economic development with environmental conservation and cultural preservation in tourist destinations.

Ar. Dwijomala Hanjabam Asst. Professor, Mizoram University

She is an architect and an urban designer. Before embarking into academics, she was working in the consulting industry with Ernst & Young with experience ranging from real estate, affordable housing, tourism sector, hospitality, industrial development etc. She has worked on international consulting projects in Nepal, Sri Lanka and the US. After her stint with EY, she worked with as an associate consultant with Fortress Financials for the Government of Kerala to develop Thirty Years Advance Vision and Development Plan for Tourism Sector in Kumarakom and Kovalam. She has been in academics for almost 11 years. She has taught in colleges in Mumbai, Assam, Bhopal (SPA) and currently is part of Mizoram University. She is also a member of the apex committee for Streets for People, Smart City Aizawl and researching on the need for culture in social housing schemes.

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CONFERENCE KEYNOTE SPEAKERS

Professor Ayyoob Sharifi
Hiroshima University, IDEC Japan

Ayyoob Sharifi is a Professor at the IDEC Institute, Hiroshima University. He also has cross-appointments at the Graduate School of Humanities and Social Sciences and the Graduate School of Advances Science and Engineering. His research is mainly on the interface of urbanism and climate change mitigation and adaptation. He actively contributes to global change research programs such as the Future Earth and has served as a lead author for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Before joining Hiroshima University, he was the Executive Director of the Global Carbon Project, leading the urban flagship activity of the project. Prof. Ayyoob is interested in pursuing research at the interface of climate change and urban planning and his contribution in the areas of urban Planning and Policy; Land Use; Climate Change Mitigation and Adaptation; Urban Carbon; Nature-based Solutions; Green Infrastructure; Urban Heat Island; Resilience; Urban Form; Assessment Tools; Smart cities; Sustainable Cities; Post-COVID cities in noteworthy which gets reflected in his research work and extensive publications. He has served as Editor, Guest Editor, and Reviewer to many reputed journals. He has more than 27 book publications to his credit and is actively involved in Invited Lecture, Oral and Poster Presentation

Prof. Ramesh Srikonda
Director, SPA Vijayawada

Prof. Ramesh Srikonda hails from Guntur District, Andhra Pradesh, India. He is an alumna of JNTU Hyderabad, Anna University Madras and IIT Delhi. He served in the Central Government through UPSC – Central Architectural Services (CAS) in 1985 (Central PWD) and rendered his professional services in various capacities such as Deputy Architect, Architect, Regional Architect, Senior Architect, Chief Architect and Director of Planning, slum & JJ, department. Currently Professor & Director, SPA Vijayawada. His areas of interest and expertise are Energy Efficient Design, Energy Conservation Studies in Buildings, Materials and Space Conditioning Options, Affordable Design of Settlements, Climate Resilient Design, Vernacular Architecture, and neighborhood settlement Planning Models

Prof. Srikonda has initiated and associated with the development of the New Course Structure for M. Arch with a focus on Sustainability in Architectural Built forms and Architectural Design with due consideration to Climate change, ecological/environmental sensitivity, and energy efficiency. He is a member of many distinguished professional bodies such as a Fellow Member of the Indian Institute of Architects, Associate Member of the Institute of Town Planners India, Fellow member of the Indian Society of Lighting Engineers and a Life member of the Indian Society of Ergonomics.

Rafiq Azam
Architecture for Green Living, Bangladesh

Rafiq Azam is the principal architect of Shattoto, an architecture firm in Dhaka that specializes in "architecture for green living." Rafiq Azam completed his studies at Bangladesh Engineering University (BUET), Dhaka in 1989. In 1989 started practice with the STHAPOTIK-architects, engineers & planners as a partner where he served until April 1995. Since May 1995 he has been operating his own firm. He has received numerous awards for his work in art and architecture, including the Commonwealth Associations of Architects Robert Matthew Lifetime Achievement Award 2022, AD100 Most Influential Names in Architecture 2018, World Architecture Community Award three times in 2008-09, being shortlisted for the Leading European Architects Forum Award in 2009, recognized as the Emerging Architect of the world by Urban Land USA in 2008, winning the AR Emerging Award in London in 2007, being a finalist for the Aga Khan Awards for Architecture in 2004 and 2007, and receiving the Berger Award for Excellence in 2007. Winner of the Asia Pacific Culture and Design Award in the USA in 2007, and recipient of the South Asian Awards for Architecture four times.

Mr. Azam is a visiting faculty member at various universities including The National University of Singapore, NED University Pakistan, North South University, the University of Asia Pacific, Ahsanullah University of Science & Technology, and Brac University Dhaka in the Department of Architecture. Azam has delivered lectures worldwide at various colleges and seminars. Shatotto aims to discover the forgotten history and heritage of Bengal and reconstruct the missing connection between its urban and rural culture. Shatotto aims to reconcile architectural principles with the contemporary challenge of responsible design to stimulate dialogue among individuals, communities, and the environment for the betterment of society.

Prof. Pratyush Shankar
Professor, Navarachana University

Pratyush Shankar is a practising architect and an academician. An alumna of MS University Baroda & CEPT University Ahmedabad, he is currently the provost of Navrachana University and the Dean of SEDA, Navrachana University, Vadodara, India. He is also a Guest Professor at the Mundus Urbano Program at the Architecture Faculty, TU Darmstadt, Germany. He was awarded the Alexander Von Humboldt Fellowship in 2015 and was hosted at the University of Bonn, Germany. AR Pratyush Shankar was associated with the Faculty of Architecture at CEPT University for more than two decades. While at CEPT University, he held the position of Acting Dean of Architecture apart from being the head of the undergraduate program. He was also appointed as Director of the Undergraduate Office; a CEPT University level position where he brought about major reforms by introducing choice-based learning, flexible curriculum, and major/minor-based PG programs.

He frequently contributes to lectures and publications and has mentored numerous works. His recent publication includes a book titled “History of Urban Form: India” published by Oxford University.

CONTENTS

BUILT ENVIRONMENT CONTEXT, IDENTITY & SOCIETY

BUILT ENVIRONMENT AND WELL-BEING

BUILT ENVIRONMENT & TECHNOLOGICAL ADVANCEMENT

Barrier Free Design – Accessible to All

Dr. Satpal [1], Shalini Mishra [2]

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Abstract— Barrier-free design, often called inclusive design, represents a holistic approach to architectural planning that aims to create accessible and welcoming environments for all. It transcends simple compliance with building codes and regulations by focusing on eliminating physical, sensory and cognitive barriers that can hinder individuals' full participation in society. Accessibility for all is about elements and places that can be used by everyone. It is aimed at people with or without disabilities, children and the elderly population as different target groups. This research explores the fundamental principles and transformative impact of these design philosophies in creating environments, products and services that serve the diverse needs of individuals, regardless of their abilities or backgrounds. The need for this research arises from the glaring gaps in our built environment when it comes to accessibility and inclusiveness. Barrier-Free Design steps in to remove barriers, ensuring that walking is not a puzzle and that everyone can participate without feeling left behind. A single design approach cannot meet people's different needs. Therefore, Universal Design aims to design elements and spaces by providing options and choices for their use, thus creating an inclusive environment for everyone, which can then prove beneficial to people in many ways. The aim of this study is to explore how universal design makes spaces inclusive and usable for people with and without disabilities, and how we can design for a wider audience, providing equal opportunities for the independence ease and safety of different types of users in our society. The objective of this study is to Propose innovative solutions and design strategies that prioritize the independence and dignity of all users. This research will explore the national and international universal design standards for accessibilities. Case studies of successful inclusive designs, Surveys or interviews with users, Analysis of existing design guidelines and standards. Therefore, the inclusion of universal design promotes maximum participation in society. This approach aims to avoid stigma and inequality. It is a design intervention that recognizes differences by addressing the different needs of different groups of people.

Keywords: Barrier Free Design, Design for All, Inclusive Design, Accessibility, Disability

INTRODUCTION

"According to Census 2011, out of the 121 Cr population in India, about 2.68 Cr people are "disabled", which is 2.21% of the total population" "(Ministry of Statistics and program implementation, 2021). Targeted initiatives for the well-being of disabled people are important at a time when "integrative development"is highlighted as the best path to sustainable development. This highlights the need to improve our country's accessibility statistics for people with disabilities (Mansell, 1978). Creating environments that are inclusive and accessible to people of all abilities is a fundamental issue in contemporary design. Barrier-free design is at the forefront of resolving this issue to guarantee equal access for all. Its goal is to eliminate physical and environmental barriers.

The concept of accessible design has evolved and transcends its traditional definition. At its core, accessible design is about consciously creating environments that eliminate or minimize barriers, ensuring access and usability for all, regardless of physical ability, sensory perception, or cognitive ability (Chew, 2009). The aim of this research is to provide an in-depth examination of the theoretical foundations, historical deve lopment and practical implications of accessible design, with a focus on its role in promoting inclusivity and accessibility for all people. (DUNCAN, 2021). The potential of barrier-free design to revolutionize the way we envision and build environments renders it noteworthy. Apart from eliminating tangible limitations, it also fosters a sense of acceptance and dignity for those with disabilities, so promoting their social integration and engagement in many life pursuits.

Barrier Free design refers to a comprehensive and intentional approach to planning and creating environments that eliminate barriers that impede access, navigation and use by people with different abilities. This involves strategically removing physical, sensory and cognitive barriers within the built environment and promoting an inclusive atmosphere that meets the needs of all (Edmonton,2008). Accessible design is not just compliance with legal regulations, but a transformative philosophy that aims to create spaces in which all people can fully participate in various activities, thereby promoting social inclusion and equal opportunities (Edmonton, 2008).

“The term Barrier free design was coined in the 1950s to describe the attempt to remove physical barriers from the built environment for people with disabilities.”Disabilities. Accessibility planning helps create a built environment that is usable for everyone. (Welch, 1999) In addition to providing benefits to people with For disabilities, limited mobility, or parents pushing strollers, accessible design helps create a more inclusive and mobility-enhancing built environment for all users. (Amirthalingam, 2012)

Accessibility for all encompasses the broader goal of ensuring that the built environment, products, services and information are designed and provided so that they are usable and understandable by everyone, regardless of their abilities or disabilities (J.L.Bennett, 2017). It goes beyond physical structures to include digital and communication accessibility, ensuring that information is equally available and understandable to people with different sensory and cognitive abilities (Mansell, 1978). Essentially, accessibility for all aims to remove barriers and create an inclusive society in which everyone can actively participate and enjoy equal opportunities (Lueck, 1992).The purpose of this research is to investigate the foundational concepts of barrier-free design, assess its noteworthy impact on inclusivity, and offer practical recommendations for raising the bar in the domains of architecture and design.

Theoretical framework

Accessibility of the higher education institutions

(Kirno, 2022)"Accessibility of People with Disabilities in Higher Education Institutions" is the title of a research project. It has been successfully enacted by the Indonesian government to forbid universities from rejecting applicants with disabilities. Regulation No. 46 of 2017 concerning Special Education and Special Services Education in Higher Education, issued by the Minister of Research and Higher Technology Education, makes this clear. Sadly, most universities still refuse to admit students with disabilities to their campuses. Scholars have endeavored to ascertain the optimal choices for individuals with disabilities and the prerequisites for admission to tertiary institutions, together with the rationales for universities' rejections of these candidates. because it describes intricate and complex events and distills the essence of participants' actual experiences with a particular issue.

Challenges faced while accessing the higher education institutions

The subject of this research is "A case study of students experiencing mobility disturbances at a university in Ghana: Student Experience people with disabilities in inaccessible built environments." The purpose of this study is to look into the experiences of a female student with unusual mobility challenges as well as how Ghanaian educational institutions cater to students with special requirements. It would be inappropriate, the paper argues, to defer to the particular needs of impaired students, regardless of their location or the accessibility issues they encounter. The inaccessible academic environment necessitates adequate action in this regard. Like all other students, he must utilize his human right to an education. Remodeling as well as the creation of infrastructure that is suitable for accessibility and accommodaation on campus is required (Tudzi,2020).

Assessment of accessibility policies in educational institutions

"Disability considerations for infrastructure programs" Review. The UK Department for International Development collaborated with DAI (which includes HTSPE Limited) and IMC Worldwide Limited (DFID) to produce the Climate Environment, Infrastructure and Livelihoods Evidence of Professional and Applied Knowledge Service Program (CEIL PEAKS). Each and every DFID policy and program aims to be inclusive and accessible to everyone, including the disabled and marginalized individuals based on their age, gender, geography, or socioeconomic standing (Steele,2016). Using this quick table research method makes it easy to find evidence of how people with impairments are impacted by inaccessible infrastructure. The article makes several suggestions on how to incorporate universal access into the infrastructure project. Read the DFID Disability Framework "(Leaving No One Behind,2014)".

Table 1: Exploring key principles and theories

Principle / Theory	Description
Flexibility	Spaces designed to accommodate diverse needs and preferences.
Simplicity	Intuitive design that is easily navigable by a wide range of users.
Equitable Use	Ensuring designs are fair and do not disadvantage any user group.
Social Model of Disability	Emphasizes addressing societal barriers rather than focusing solely on individual impairments.

Analyzing Core Concepts and Theories:

Fair usage, adaptability, and simplicity are some of the fundamental ideas that underpin barrier-free design. The concept of "universal design" holds that items and environments should be as accessible as possible to all people, without the need for any type of adaptation ideas like "Social Model of Disability".

Several key principles and theories underpin accessible design, with the goal of creating spaces that are universally usable.

Identifying Gaps in the Literature:

There are still several gaps in the literature despite the wealth of studies on barrier-free design. It has not been sufficiently acknowledged that various user groups have complex experiences, and further study is needed to comprehend the cultural dimensions of inclusion in architectural practices. In addition, greater investigation is required into the ways that technology is evolving and how barrier-free design may benefit from it. This study aims to bridge these gaps by examining the social and cultural aspects of inclusion in architectural environments and considering the dynamic link between technology and barrier-free design.

Design Considerations (As per NBC)

Anthropometrics

Distribution of Space- Ensure that there is adequate space for those who require walkers, crutches, wheelchairs, and those who are assisted by others. Consider the wheelchair user's reach range, both forward and sideways, as well as the typical wheelchair size in your area (1050 x 750 mm).

Controls Accessibility- Windows and doors that are placed no higher than 1400mm above the finished floor should have locking and opening mechanisms that are easily operated with one hand.The recommended distance between power outlets, door knobs, and switches from the finished floor is between 900 and 1200 millimeters.

Impaired Ability to Walk Partially- Keep the minimum path width for those using crutches at 900mm.Handrails and non-slip flooring are recommended for high-traffic locations such as stairwells, ramps, and hallways with level changes to enhance safety.

Visual Impairment- Ensure that talking signs, braille information boards, and guiding blocks are available for individuals who are blind or visually impaired.Make sure there are no objects sticking out from walking areas and that the contrast is good enough for people with vision impairments.

Hearing Disabilities- Information boards should have easily understood presentation.Use layout schematics and lit signage to help those who are hard of hearing.

Walks and Paths- Ensure that your paths are level, smooth, and at least 1200 mm wide.For walks longer than sixty meters, provide rest spaces; steer clear of obstructions and uneven terrain.

Parking- Surface parking spots shall be available for those with physical disabilities, provided that they are no closer than 30 meters from the building's entrance.Parking spots ought to be at least 360 mm wide and have the wheelchair accessible sign clearly visible

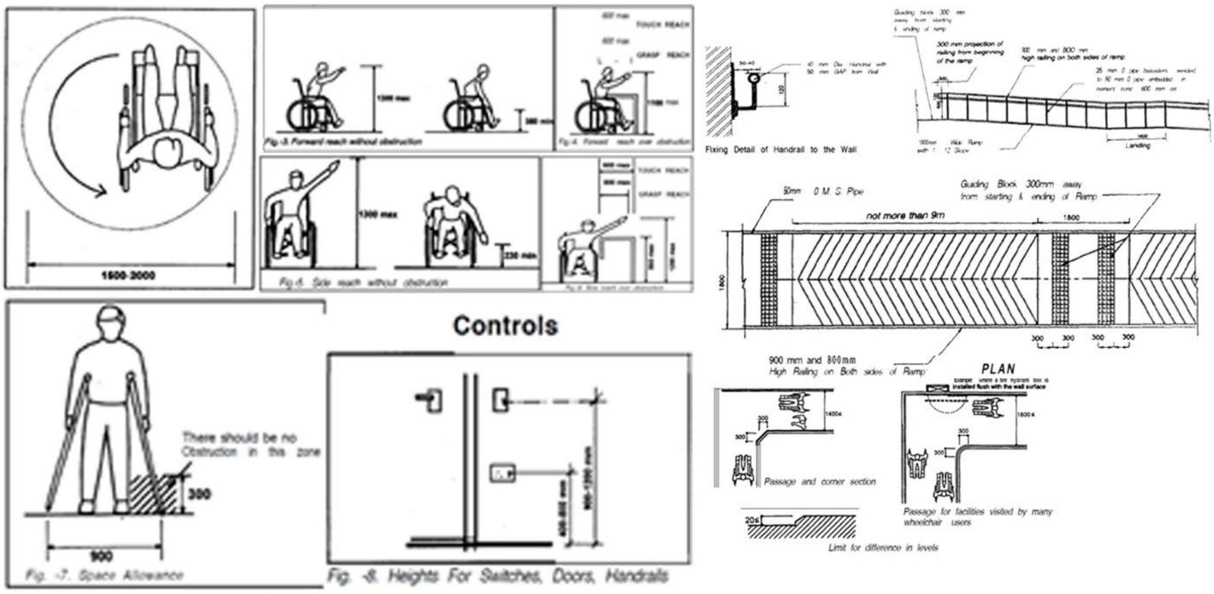


Figure 1 : Design Considerations for Anthropometrics for wheelchair, crutches, toilets, Ramps, Corridors. Reference: NBC,2016

CASE STUDY

Aligarh Muslim University, Jamia Milia Islamia

Physical Accessibility

For pupils with special needs and those with impairments (such as locomotor difficulties), physical accessibility is crucial. Physical impediments are present in the majority of higher education institutions, particularly on university campuses. For students with disabilities, who frequently encounter a variety of physical challenges when trying to participate in university-related activities, this is especially troublesome. Architectural features, building access, classroom access, and convenient access points to adjacent campus areas including parking lots, restrooms, and elevators are examples of physical supports. Since physical accessibility is one of the most important forms of help that universities offer to students with disabilities, depending on their unique needs.

Structural Accessibility

Every building has elevators and ramps for those with disabilities. Libraries, cafeterias, labs, restrooms, and classrooms are a few examples of areas that are architecturally accessible. Students with impairments frequently encounter these institutional impediments in higher education. Both universities have updated their older buildings with ramps and elevators. However, the majority of them turn out to be malfunctioning AMU elevators. This data suggests that there are other aspects of structural accessibility that are inadequate for students with disabilities, in addition to tactile track facilities and ramps. This demonstrates quite clearly how the accessibility of support services is influenced by a number of factors, including the availability of funding, the type of institution, the way in which UGC programs are implemented, the presence of a disability cell or coordinator.

Walk and Pathway inside the University The pathways for pedestrians are elevated above the street. Wheelchair users cannot use the walking path as a result, and pupils who are blind or visually challenged run the risk of falling. People who use wheelchairs, crutches, or canes will find an extra challenge as a result of the missing tiles on the walking route. In this sense, children who are blind or visually challenged bear an extra burden. The sign is just textual, so it's hard to know if he's at the right place. Stated differently, it creates obstacles for individuals with disabilities seeking to enroll in college on their own. This is the first step toward physically harming people and destroying the self-worth of pupils who are disabled.

Signage

There are numerous directional signs located around both campuses. Because it is at a height where those with sight may see it, the sign is visible. But because of this, as well as the fact that the indicators are written solely, blind students need assistance to succeed.

Ramps

Handrails for students with visual impairments or those who require walking assistance, such as sticks, are located on both sides of the road. Handrails should run the length of a path so that those who find it difficult to move on one side can use it on the other. Students with visual impairments may find it more challenging to navigate the ramp if there are no tactile markings on the slope. large enough to fit students who use wheelchairs for mobility. clashing hues Texture indications are required at both ends of the ramp. This will help kids who have low vision recall where the road is. The path has a steep climb. Wheelchair riders who use them alone run a very high risk of being disoriented.

Interiors of Buildings

Corridors - Wheelchair-user students will find that the halls are sufficiently broad. For visually impaired children, the entire corridor is bordered with white lines, which may contribute to everyone's safety. Every hallway is poorly lit, which is a barrier for children who are blind or visually impaired. The mobility corridor does not have any touch markings for students who are visually impaired.

Lifts- For students who are blind or visually challenged, the elevator does not have an audible floor announcement system. There are no indicators for pupils with visual impairments, elevator doors opening and closing, or the arrival of different floor levels. The elevator's emergency information is written down; visually impaired pupils cannot access audio or braille devices. Room Students in wheelchairs are unable to move their chairs within the elevator due to a lack of lifts. Wheelchair-using students can find it challenging to enter the elevator due to its small entrance. The majority of the elevators in Aligarh's Muslim institutions are broken.

Canteen- A highly beautiful daily rotating menu is served at the canteen. The meal for each day is written down and shown. Students who are visually impaired may have difficulties because there is no signage for them. Deaf pupils cannot connect with shopkeepers since they do not know sign language. Students can use the tables and chairs together, however wheelchairs cannot utilize the chairs. For students with visual impairments, navigating the cafeteria may be challenging because there is no tactile signs.

Classrooms- Children who are visually impaired, deaf, or in a wheelchair are not accommodated in separate seating areas in the classroom. A large number of the institution's demonstration classrooms had desks and chairs on the floor. As a result, a student using a wheelchair is not permitted to sit in their usual spot or utilize the desk. In this class, students who use wheelchairs must have a designated desk. Students who have trouble hearing should take a seat close to the teacher in order to improve comprehension. While they are not used in every course, audiovisual aids are employed in the classroom. Students who are visually challenged cannot utilize any software, including Jaws and FM systems for kids who have hearing problems.

Library- The AMU library section, state-of-the-art computer lab facilities, a Braille service, assistive technology, screen reading software, and the most recent automatic speaking software are all provided by the Disability Unit. The library lacks any kind of visual aid or signage.signage to discourage students who are hard of hearing from accessing the library alone without assistance. The library does not have reserved seating. wheelchair-using students, despite the table's appropriate height for them. To facilitate their access to the table, utilize a wheelchair; wheelchair users can fit beneath the table thanks to the additional legroom. Students with visual impairments may have limited range of motion since they are unable to use the Braille Touch feature.

Restrooms- A few of the restrooms were created with the purpose of accommodating students who use wheelchairs or have eyesight issues. The handrails on all three sides can also provide help for pupils who are in wheelchairs or have visual problems. Nonetheless, some restrooms are devoid of handrails on all three sides. Pupils with hearing impairments were unable to locate any notice. There shouldn't be tactile floor markers for pupils with low vision.

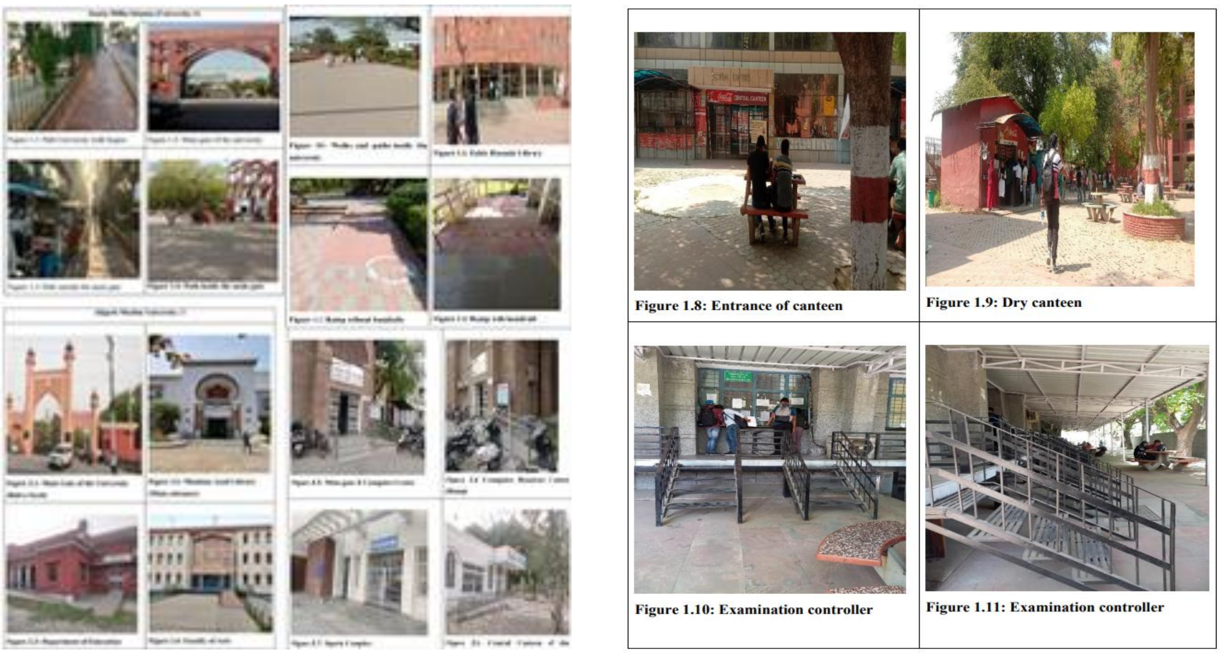


Figure 2 : Images of the AMU & JMI, reference: Author

Connaught Place, New Delhi

One important business district in New Delhi, Connaught Place, retains much of the old Garden City design. It's a non-residential, single-use environment focused on automobiles. Although the Public Works Department bungalows and colonial architecture of Connaught Place still stand, the Delhi Government, in collaboration with the National Centre for Promotion of Employment for Disabled People and the Council of Architecture, initiated a project to make the area more attractive and barrier-free. This deliberate move aligns with the city's goal of exhibiting mobility options and accessibility for the elderly and disabled globally in conjunction with its hosting of the 2012 International Transed Conference. Efforts to Promote Inclusivity:

The Delhi Transport Corporation and the Metro system have made proactive steps to encourage inclusivity. Ramps are part of Bus's user-friendly design.

Govt.-NGO Collaboration- For-profit companies and governmental organizations have played a crucial role in enhancing Delhi's accessibility. Programs such as SAMARTHYAM and SVAYAM aim to transform public spaces. In partnership with the Delhi government, SVAYAM has adapted historical sites including Qutab Minar and Red Fort to provide universal accessibility. SAMARTHYAM evaluates, develops, and disseminates designs that are internationally accessible in collaboration with governmental organizations.

Success Narratives- As a result of Samarthyam's Accessible Delhi campaign, which was led by other businesses, universal accessible elements have been installed in significant locations like Connaught Place, New Delhi Railway Station, Nizammuddin Station, Anand Vihar Railway Station, and Sarai Kale Khan Bus Terminal.

Current Landscape and Future Challenges- There is a consensus that more work needs to be done, even if the Delhi Administration's dedication to accessibility for individuals with disabilities is remarkable. The nature of disability and the difficulties people encounter necessitate constant conversation and diverse approaches to solving problems.

RESEARCH METHODOLOGY

In the course of the investigation, three techniques are employed to collect data. These methods were chosen to ensure that the collection of data proceeded smoothly and that the data met the goals of the study, which recommended inclusive accessibility on commercial streets based on the public as well as the opinions, demands, and preferences of the disabled community regarding street accessibility. Among the techniques are:

i) Observation ii) A survey questionnaire

These methods include taking pictures and utilizing a checklist form to document the research area. Thirty respondents—a mix of local and non-local people with and without disabilities—are also given a structured questionnaire.

Observation

This methodology is used to achieve both the major and secondary goals of the research. This study employs direct observation, which is the practice of observing without interfering with the objects or study participants in their surroundings (Kawulich, Barbara, 2012). The important part of the data

In order to offer accurate data and a visual assessment, the phases in the collection process include carefully observing the surroundings, paying attention to what is happening in the area, documenting, and taking images.

Phases of observation are conducted to examine and pinpoint the difficulties that users—especially individuals with disabilities (PWDs)—face when attempting to use the streets. These actions are being planned before to traveling to the study region in order to ensure the success of the observation technique.

The stages consist of planning stage, site physical observation and managing data collection.

The final stage is managing the data collection process. Information that has been collected is documented in hard copy and will be used for data analysis in the future. Tables and pictures are used to organize the data in a logical and systematic way to make data processing easier. The collected data can be strengthened with additional secondary data to yield more insightful conclusions and suggestions.

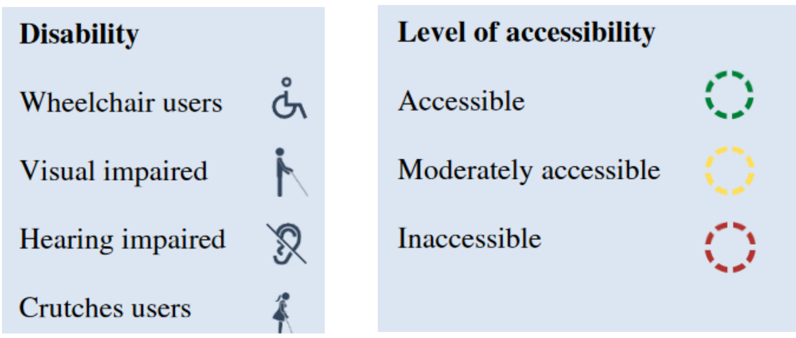
Survey Questionnaire

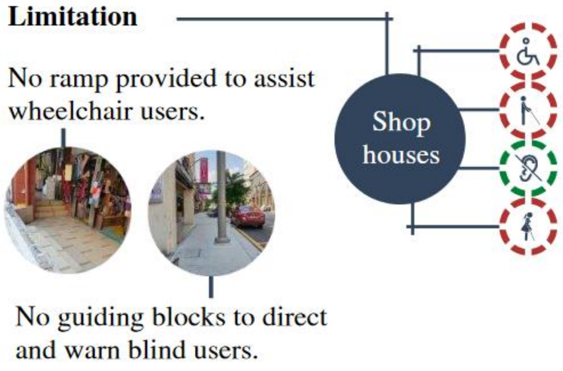
In this study, the questionnaire survey approach was used to collect data on the characteristics of the disabled population using commercial streets, the percentage of each kind of handicap, and—above all—the suggestions and counsel from all people to provide equitable accessibility on commercial streets based on their needs and preferences.

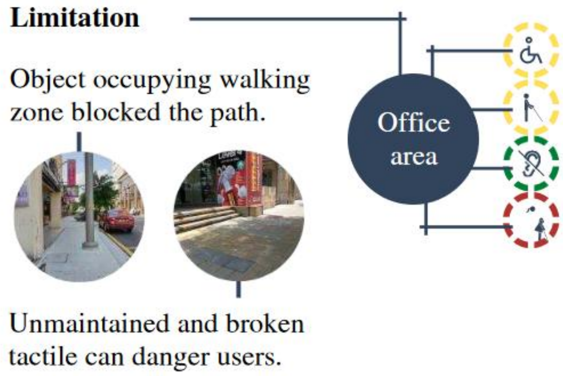
Answers to several of the questionnaire's questions must be provided by respondents. Thirty respondents—thirteen visitors and residents of Connaught Place, New Delhi—both disabled and non-impaired, make up the study's target sample. As said earlier, this questionnaire survey approach aims to achieve the research objectives, one of which is to suggest inclusive and universal accessibility for commercial routes.

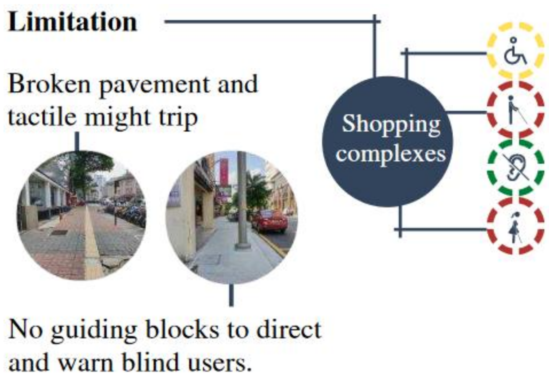
Observation Analysis

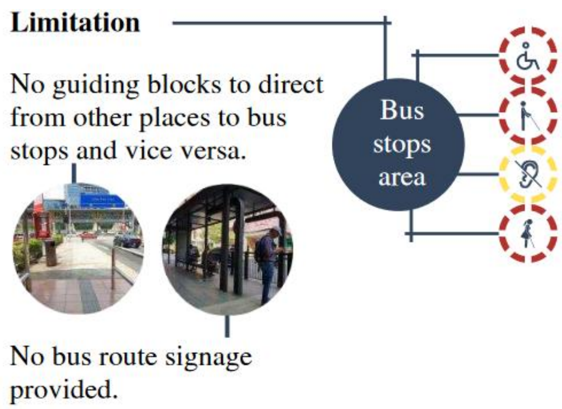
Based on the study region's perceived density or volume of traffic on commercial highways, the study region was divided into five main regions. The five main areas include bus stops, pedestrian crossings, office building locations, shopping centers, and store houses. The areas were **e**very piece of information found was scrutinized, recorded, and observed. The results of the observation are shown below.











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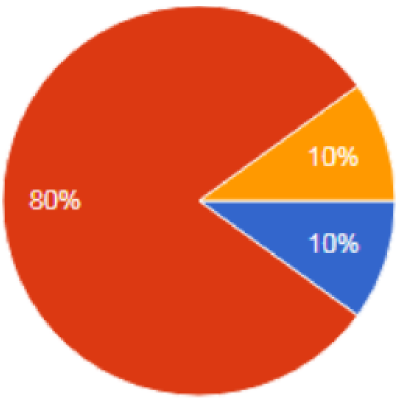
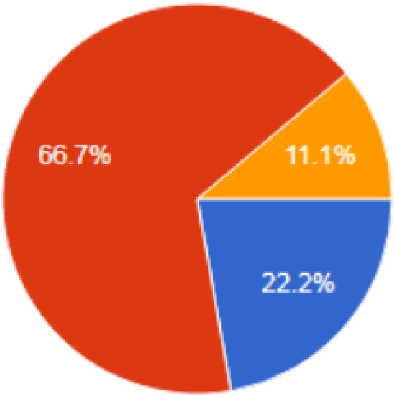


Level of Accessibility by all types of people

Street Elements	Level of Satisfaction
Footpath	Fair
Step Ramps	Poor
Ramps	Fair
Stairs	Good
Handrails	Fair
Guiding Blocks	Fair
Signs and Symbols	Poor
Parking	Fair
Floor Finishes	Fair
Pedestrian Crossings	Poor
Access to Bus Stops	Poor

Satisfactory Level of Street Elements

Barrier and Limitation



Barriers	Percentages
Footpath too Narrow	90%
Step blocked access to PwDs	50%
No digital signage to assist hearing impaired	90%
No barrier between pedestrian and vehicles	90%
Objects occupy walking zone	40%
Signage font too small	30%
Lack of safety design feature	70%
Lack of Maintenance	90%

Ability to access and get around the street

Data analysis

Aspect	Jamia Milia Islamia (JMI)	Aligarh Muslim Unive--rsity (AMU)	Connaught Place New Delhi
Sensory Environment	Tactile guiding tiles, warning tiles with some inconsistencies.	Issues in walk paths, lack of tactile cues, and warning tiles.	Challenges in walk paths and tactile cues.
Library	Provides Braille services, advanced computing facilities, screen-reading software.	Lack of signage and visual indicators.	Lack of signage and visual indicators.
Classrooms	No special seating arrangements, lack of audio-visual aids or software.	Lack of special seating and audio-visual aids.	Lack of special seating and audio-visual aids.
Canteen	Pictorial and written menu, lack of signages, fixed seats, and tables.	Issues with signage and tactile marking.	Issues with signage and tactile marking.
Restrooms	Special restrooms with handrails but lack tactile marking and signages.	Challenges in restrooms with no tactile marking or signages.	Challenges in restrooms with no tactile marking or signages.
Technology in Use	Use of assistive technology, Braille services, and hearing aids.	Some use of assistive technology in Maulana Azad Library.	Use of assistive technology in Maulana Azad Library.

Aspect	Jamia Milia Islamia (JMI)	Aligarh Muslim Unive--rsity (AMU)	Connaught Place New Delhi
Physical Environment Layout	9 building blocks with gardens, ramps, and parking facilities	Varied building blocks with issues in walk paths and tiles.	Issues in walk paths and signage.
Physical Environment Circulation	Various ramps with varying slopes, handrails, and flat surfaces for rest.	Ramps with handrails, steep/bumpy beginnings, and width issues.	Ramps with handrails and steepness.
Accessibility - General	Inconsistent stair treads; limited elevators, challenging for wheelchair users.	Walk paths and ramps not level; non-functional lifts; limited signage	Challenges in walk paths and signage.
Accessibility - Elevators	Limited elevators, not double-sided, difficult for wheelchair rotation.	Non-functional lifts with narrow entry.	Issues in lift functionality.
Accessibility - Furniture	Lack of adjustable desks; no two-level counter at reception.	No mention of adjustable furniture.	No mention of adjustable furniture.
Corridors	Corridors with benches, 2m wide, but classrooms congested.	Wide corridors, but lack of lighting and tactile markings.	Wide corridors, but lighting issues.
Informal Spaces	Benches along corridors, gardens, dining hall, but challenges in navigation.	Challenges in circular dining hall navigation.	Challenges in circular dining hall navigation.

Connaught Place in New Delhi is not properly accessible, especially for those with physical and visual disabilities, according to the survey's findings and observations. Thus, this article advocates for inclusive accessibility to discuss the actual demands that people with disabilities (PwDs) have in the research area with regard to street provision for various uses, safety, and accessibility.Enhancing a multipurpose street with assistive technology is one option that can help individuals of all kinds of disabilities. These days, it's thought that technology is necessary to increase system and service production and efficiency. Therefore, when suitable technology implementation is used—for example, by offering pedestrian signals and signage with a variety of specifications and features to make it easier for those who are hard of hearing to get around—it is perfectly consistent with contemporary development.

Connaught Place, New Delhi, should be made truly barrier-free and accessible by implementing universal design principles in the redevelopment plan, installing accessible infrastructure (like ramps and elevators), and giving priority to inclusive public transportation (like accessible bus stops and metro stations). Digital platforms and accessible restrooms are just two examples of the services and facilities in Connaught Place that should adhere to accessibility standards. Maintaining an inclusive environment and receiving continuous feedback requires working with disability associations, Report Word performing frequent accessibility audits, and sponsoring education and awareness efforts. Other crucial elements include encouraging barrier-free behaviors, incorporating local companies, and maintaining cultural sensitivity throughout the design process. In order to address problems as soon as they arise, routine maintenance and monitoring mechanisms must be established.

CONCLUSION

People with disabilities, particularly those who are physically challenged, favored ramps that had more steps, a sufficient gradient, and handrails on both sides, according to a survey. Another challenge for people with physical disabilities is getting to bus stops.Most of the bust stops are difficult to get to because of barriers that impede and narrow the path.Furthermore, people may utilize the poor signage at the bus stop to find their way about. More signals are something that most persons with hearing impairments would like to see and are concerned about, especially at pedestrian crossings. People with disabilities (PwDs) preferred automated elevators on buses because they would save them time and facilitate access, the study found. Additionally, responders advise regular upkeep.

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Joshimath Sinking: Unveiling the Impact of Unbridled Infrastructural Development Threatening the Lives of The Locals

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Abstract— In Uttarakhand, specifically around the town of Joshimath, infrastructural development intersects with the issues involving local communities, environmental concerns, and cultural preservation. This region is a part of the sensitive Himalayan ecosystem and is extremely prone to natural disasters like landslides and flash floods, making infrastructural development a complex issue in the region (Pandey, B.W., 2020). The overnight development of cracks on roads and buildings in the town of Joshimath, is one such indication of an upcoming disaster. This land subsidence has impacted the lives of about 3000 locals (Moharaj, P., 2023). National Remote Sensing Centre found that land subsidence was "slow" between April and November 2022, with Joshimath sinking by 8.9 cm. However, between 27 December 2022 and 8 January 2023, it sank by 5.4 cm (ET Online, 2023). The report has predicted that the entire town may face an existential threat due to land subsidence. This research studies the impact of infrastructural development activities and geological instability of the Joshimath region on the lives of local communities. The research analyses the previously established facts from the various research papers and reports, visual surveys and interviews on the situation of Joshimath. The streams of unbridled construction activities have completely neglected the need of the major stakeholders i.e. the local residents of Joshimath. The issue is underlying and has been reported since 1970's, the then-formed Mishra committee's report had already stated that "Joshimath is not situated on in situ rocks. It is situated on a weathered, landslide mass of big unsettled boulders in the loose matrix of fine micaceous sandy and clayey material. The rocks are crystalline consisting of schistose gneissic and quartzitic (Ray, M., 2011)." The ignorance and incomprehension of government institutions and developers have led to homelessness and economic losses which have resulted in the emigration of masses to various neighbouring cities while also impacting their traditional livelihood, ecology and culture.

Keywords: Infrastructural development, Land subsidence, Local community, Society, Ecology

INTRODUCTION

Joshimath is a town located in the Chamoli district of the Indian state of Uttarakhand. With its serene landscapes, spiritual significance, and proximity to popular pilgrimage destinations, Joshimath has long been a revered place of worship and a gateway to adventure for countless travellers. Situated at an altitude of approximately 1,890 meters (6,200 feet) above sea level, it serves as a gateway to several popular pilgrimage sites and trekking destinations in the region (Sati, V. P., 2020). The surrounding landscape is adorned with lush greenery, alpine meadows, and snow-capped mountains, offering an idyllic setting for trekkers and nature enthusiasts. It serves as a base camp for various trekking expeditions to popular destinations such as Valley of Flowers, Hemkund Sahib, and Auli, a renowned skiing destination in the region (Sati, V. P., 2015). Adventure seekers are drawn to the town for its trekking routes, challenging trails, and opportunities for mountaineering and skiing, making it a haven for adrenaline junkies and nature lovers alike.

This town holds immense religious significance as it is one of the four 'Mathas' (Hindu Monastry) established by Adi Shankaracharya in the 8th century (Sati, V. P., 2015). Revered as a prominent religious and cultural hub, Joshimath exudes an aura of spirituality and natural splendour, attracting tourists, pilgrims, and adventure enthusiasts alike. However, beneath its tranquil exterior lies a growing environmental crisis that has garnered increasing attention in recent years: the phenomenon of Joshimath sinking. Furthermore, the town of Joshimath offers a glimpse into the local Garhwali culture and lifestyle, providing visitors with an authentic experience of the region's traditions and customs. The vibrant local markets, traditional eateries serving Garhwali cuisine, and warm hospitality of the locals contribute to the town's charm and allure (Sati, V. P., 2015). Travellers seeking a blend of spiritual enrichment, natural beauty, and adventurous escapades find Joshimath to be a captivating destination that encapsulates the essence of Uttarakhand's cultural and natural heritage.

For residents of Joshimath, the first week of the new year 2023 opened to cracks emerging on roads and the walls of buildings (Figure 1). Residents had been observing such cracks since October 2021, after the flash floods that had claimed more than 200 lives (Aljazeera, 2023). The current situation (as of December 2024) is that, in Joshimath, 868 structures have developed cracks, and 181 have been declared unsafe so far resurfacing the fear and uncertainty amongst the locals (IndiaToday, 2023).

Figure 1: Cracks developed inside of a house in Joshimath after the first week of January 2023
Photo Credit: Tanmay Pandey, Independent Journalist, March 2023

In July of 2023, a 6-feet hole appeared in Sunil ward and a long crack on Auli-Joshimath road triggered agitation amongst the locals and resulted in the relocation of 11 more families to the relief centres (Ashutosh,

M., 2023). The paper aims to study the aftereffects of the land subsidence on the local communities in terms of migration and economic impacts. The research is based on an ethnographic study, for which interviews, visual surveys and study of available literature were done to deepen the cognizance of the Joshimath subsidence and its impact on the local communities.

Settlement of the city of Joshimath

The term "Joshimath sinking" refers to the gradual subsidence of the town's terrain, leading to a significant decline in its ground level (Jha, R., 2023). This alarming phenomenon has raised concerns about the stability of the town's infrastructure, the safety of its inhabitants, and the long-term viability of its existence. The sinking of Joshimath is not an isolated incident; it represents a larger pattern of environmental degradation and geological vulnerability that threatens many regions in the fragile Himalayan ecosystem (Jain, S.L., 2010). According to various on-ground reports by several national and international news agencies, 678 buildings had developed cracks and as a result, about 600 families were relocated and moved to shelters (Ashutosh, M., 2023). The majority of the buildings that had developed cracks did irreversible structural damage and have been demolished since (Figure 2).

Figure 2: Demolished building deemed unfit after developing huge cracks

Photo Credit: Tanmay Pandey, Independent Journalist, March 2023

METHODOLOGY

To understand the impact on the locals at large, it was needed to study the demography, settlement pattern, economic activities and the growth and establishment of the town. The establishment of the city of Joshimath, occurred in several phases, each marked by significant developments and the town's growing importance as a religious and cultural centre and also a base for winter adventure activities. The first phase marks the establishment of Joshimath as one of the four Mathas (monasteries) by Adi Shankaracharya, a revered Indian philosopher and theologian, during the 8th century (Sati, V. P., 2020). He chose Joshimath due to its strategic location in the Himalayas and founded it as a monastic centre to facilitate the study and dissemination of Vedanta philosophy and the Advaita Vedanta school of thought. The town's initial development primarily revolved around religious activities and the cultivation of spiritual knowledge.

In the subsequent phases, Joshimath's religious significance continued to grow, particularly concerning the annual Char Dham Yatra pilgrimage. The town served as a vital stop for pilgrims on their journey to the holy sites of Yamunotri, Gangotri, Kedarnath, and Badrinath. Its proximity to the Badrinath Temple, one of the holiest Hindu shrines dedicated to Lord Vishnu, elevated its importance as a religious hub in the region. The town's religious institutions expanded, and its infrastructure gradually developed to accommodate the growing number of devotees and travellers (Sati, S. P., 2023).

During the medieval period, Joshimath experienced a cultural and spiritual flourishing, with the town becoming a centre for learning, art, and religious discourse. Monks, scholars, and devotees flocked to Joshimath, contributing to the town's intellectual and cultural vibrancy. The teachings of Adi Shankaracharya and the Advaita Vedanta philosophy continued to influence the town's spiritual fabric, shaping its identity as a bastion of Hindu religious, thought and tradition.

In the modern era, particularly from the 20th century onward, Joshimath underwent significant development to accommodate the burgeoning tourist influx (Perlik, M., 2019). The town's infrastructure expanded to include modern amenities such as hotels, guesthouses, restaurants, and transportation facilities, catering to the needs of the growing number of tourists. Its proximity to popular trekking destinations and skiing resorts, such as Auli, further solidified its position as a sought-after destination for adventure tourism and generated much traction in the area.

Joshimath retained its cultural heritage, embracing its religious roots while adapting to the evolving needs of travelers and tourists. The town's multi-faceted development and its continued significance as a religious, cultural, and adventure tourism hub have also promoted a heavy influx of population living in the nearby villages in search of jobs. The expansion of the city happened haphazardly without proper planning. To further understand the expansion and its impact we also studied the different types of settlements in the city.

Types of settlements and their growth in the city of Joshimath

A 2018 survey of four towns preceding Joshimath on the Badrinath Temple route found that 57.5 percent of the households were engaged in tourism services, with 37.5 percent exclusively dependent on tourism again indicating the need and growth in hospitality buildings in the area (Kumar, S., 2023).

Joshimath is a blend of traditional mountain lifestyles with modern amenities to accommodate the needs of both locals and the increasing number of tourists and pilgrims. The town features residential areas characterized by a mix of traditional and modern dwellings, with architecture reflecting Nagara and Garhwali styles along with contemporary housing styles. However, there's a proliferation of small residential structures, hotels, guesthouses, etc. not following established protocols. Religious institutions, including ancient temples and ashrams, play a crucial role in the town's spiritual ambiance and community bonding. Vibrant markets offer local goods and handicrafts, providing a glimpse into Garhwali culture. Essential facilities have expanded to meet the growing tourist demands, including guesthouses, hotels, medical facilities, and transportation services. The town attracts locals from nearby villages seeking better services, education, and employment opportunities, leading to unplanned settlements, particularly on critical sloping sites. A 2018 survey along the Badrinath Temple route revealed a significant dependency on tourism-related activities, indicating the importance of hospitality buildings in the area (Sharma, S., 2019). The dynamic blend of tradition and modernity, coupled with tourism-driven changes, shapes the unique character and challenges of human settlement in Joshimath further contributing to the current situation.

Causes of the land subsidence

After studying multiple reports and studies on the topic and visual survey by our collaborator Mr. Tanmay Panday it has been inferred that the sinking of Joshimath is influenced by a complex interplay of geological, climatic, and anthropogenic factors. The region's geological composition, primarily consisting of sedimentary rocks prone to erosion, coupled with the constant forces of wind, water, and glacial movements, contributes to the gradual weakening of underlying rock formations and subsequent land subsidence (Maurya, A.T., 2017). Climate change exacerbates the issue, as rising temperatures accelerate glacial retreat, reducing ice mass and leading to rebounding or isostatic adjustment, further destabilizing the fragile geological structures. Human activities, such as unregulated construction, quarrying, and encroachment on riverbeds, disrupt the natural drainage system, amplify soil erosion, and alter hydrological patterns (Jain, S.L., 2010). Recent reports highlight the role of rampant construction in the spring zone as a significant contributor to the subsidence, causing groundwater bursts and cracks. Population growth and inadequate waste management also have added stress, with improper waste disposal contaminating soil and water bodies (Singh, S., 2018). The sinking phenomenon in Joshimath reflects a multifaceted challenge requiring holistic mitigation strategies to address both natural and human-induced factors.

Currently a number of large scale infrastructural projects are running in and around Joshimath which are being termed as the major contributors of the subsidence (EJ Atlas, 2021). Following is the list of such megaprojects in the area –

• NTPC's Tapovan Vishnugad Hydroelectric Project - 558 MW

• Char Dham road project - 12000 Cr and 889 Kms long (total project) - Helang Marwari Bypass Road under this scheme

• Joshimath - Auli Ropeway

• 444 MW Vishnuprayag Pipalkoti project

3. Potential consequences on the locals and ecology

The sinking of Joshimath carries significant consequences for both the town's residents and the surrounding environment. The instability of the terrain poses a serious risk to critical infrastructure, including residential buildings, roads, and essential services. As the ground subsides, the development of cracks and fissures jeopardizes the structural integrity of constructions, heightening the vulnerability of the built environment. Additionally, the sinking phenomenon has detrimental effects on the local ecosystem. Erosion and landslides leading to the loss of vegetation and habitats disrupt the intricate balance of the ecosystem, adversely impacting biodiversity and jeopardizing the survival of various plant and animal species (Jha, R., 2023). Moreover, the release of sediment into rivers negatively affects water quality and aquatic life, presenting challenges to both human and ecological health.

Impact on the locals

The impact of the sinking of Joshimath has been investigated through a combination of visual assessments and personal interactions with the local residents. According to insights gathered from discussions with those who have already relocated to cities like Dehradun, Gopeshwar, and Srinagar, it is apparent that the decision to move was driven by a complex interplay of above-stated factors. Despite recognizing the potential of their hometown, individuals prioritized the safety of their families, reflecting a significant concern for the well-being of their loved ones in the face of the environmental challenges posed by the sinking phenomenon.

Approximately 90% of these relocated families chose their new cities, not only for safety reasons but also due to existing ties, either in the form of extended family members residing there or established business associations. This suggests that social and familial networks played a crucial role in influencing the relocation decisions. The multifaceted nature of the decision-making process highlights the nuanced considerations that individuals weigh when faced with the need to move away from their ancestral town.

However, it's noteworthy that some affected families remain in government shelters within the city, expressing a desire to return to their homes once the situation stabilizes. These families often engaged in small businesses or working in various job roles, face limitations that restrict their options for relocation. Economic ties to the region, coupled with the challenges of finding suitable opportunities elsewhere, contribute to their decision to stay close to their ancestral town despite the uncertainties posed by the sinking phenomenon. This complex interplay of familial, social, and economic factors underscores the intricate challenges faced by those impacted by the environmental changes in Joshimath.

Temporary Mitigation efforts by government and non-government agencies

Recognizing the critical nature of the situation, both governmental and non-governmental organizations have taken some temporary measures to address the sinking of Joshimath. These initiatives involve the implementation of stringent regulations on construction practices, the promotion of sustainable urban

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planning, and the dissemination of awareness regarding environmental conservation. Authorities have prioritized the establishment of early warning systems for landslides and floods, enhancing disaster preparedness measures, and relocating vulnerable settlements to safer areas (Indiatoday, Webdesk, 2023). Scientific research and monitoring programs, including geotechnical investigations such as geological mapping and subsurface exploration, are essential for gathering crucial data on subsidence patterns and guiding effective mitigation strategies. The integration of advanced remote sensing techniques like satellite imagery and LiDAR has proven instrumental in mapping and monitoring changes in the terrain. Collaboration between the CSIR-Central Building Research Institute Roorkee and the National Disaster Management Authority (NDMA) has resulted in recommendations for developing a disaster-resilient model town to rehabilitate those displaced from Joshimath (Jha, R., 2023), showcasing a comprehensive and coordinated approach to address the multifaceted challenges posed by the sinking phenomenon.

CONCLUSION

The study establishes that there are multiple factors responsible for the Joshimath situation. However, the number of megaprojects like highways and power plants that are important benefactors for local economic growth leading to urbanization and migration of masses to cities like Joshimath, also impact heavily on the local ecology one such effect being the issue of land subsidence in the area.

The migration pattern in Joshimath has seen a curious case of reverse immigration. The pattern of inflow of population has seen a major decline since the visible signs of cracks and subsidence of land started appearing in January of 2023. Furthermore, the majority of the population has started relocating to nearby cities like Dehradun creating an uncalculated load on these cities as opposed to the heavy immigration noted in the past. The local population has also suffered major economic losses in terms of their homes and businesses. There is lacunae of genuine studies on the part of major stakeholders in various megaprojects running in the surroundings of Joshimath, these include both government agencies, who have been unable to implement restrictions and suggestions proposed by the Mishra Committee and also the construction companies involved who have presented the government with either fabricated data or selective information as per their convenience.

Apart from the suggestions made in various studies especially a report by ORF (Observer Researcher Foundation) India in February 2023 (Jha, R., 2023), we would also like to add a few more recommendations which further include locals as a major stakeholder.

• Awareness: Effective mitigation efforts for the sinking of Joshimath hinge on robust public awareness campaigns and active community involvement. Engaging the local population in sustainable practices, such as responsible land use, efficient waste management, and conservation initiatives, is pivotal for alleviating anthropogenic stress on the environment and fostering a shared sense of responsibility.

• Collaboration: Through comprehensive research, collaborative programs, and public awareness initiatives, it is possible to navigate the challenges posed by the sinking of Joshimath and pave the way for a resilient and sustainable future for this Himalayan town. Addressing underlying causes, implementing effective mitigation measures, and nurturing a culture of environmental stewardship can not only safeguard Joshimath but also preserve the delicate ecosystems of the Himalayas for future generations.

• Traditional Architecture: Revisiting traditional architectural styles, such as the Koti Banal Architecture, is considered a potential solution. Experts recommend a temporary halt to development and hydroelectric projects in the region. Urgently relocating residents to safer areas and reimagining town planning to accommodate changing geographical factors are immediate priorities.

• Upgrading drainage services: Critical issues, such as poor drainage and sewer management, causing soil instability, require focused attention. The state government has tasked the irrigation department to create a new plan for the drainage system. Additionally, experts propose replantation in vulnerable areas to enhance soil retention, calling for coordinated efforts involving government, civil bodies, and military organisations like the Border Roads Organisation (BRO) to rescue Joshimath.

• Improving weather forecasting technology: The weather forecasting technology based on satellites and Doppler weather radars is essential in Uttarakhand. The state government's commitment to taking scientific studies seriously, elucidating the reasons behind the crisis, is crucial for steering away from unsustainable development practices and proceeding towards a more sustainable future.

• Unbiased research: The studies and media reports had already warned about the delicate nature of the Himalayan region, specially areas around Joshimath instead the construction activities were not restricted even after the early signs of subsidence near the Vishnugadh power plant and these projects were approved after presenting selective researches supporting the particular project.

In conclusion, the sinking of Joshimath stands as a pressing social as well as environmental crisis demanding urgent attention and collaborative endeavours to safeguard the well-being of its residents and preserve the region's ecological heritage. The convergence of geological susceptibility, the impacts of climate change, and human activities has given rise to a multifaceted challenge, emphasising the necessity for interdisciplinary approaches and the incorporation of sustainable measures.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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.Perceiving Social Sustainability in the Backdrop of the Present Mall Culture of Kolkata

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Abstract— The rapid urban sprawl has paved a way for the development of expansive shopping malls in Kolkata outlining the urban spatial and socio-cultural transformation. These malls witnessing a shift in consumer purchase patterns driven by increased affordability and brand consciousness have gradually been transformed into gathering places—a rendezvous for socializing. With the extensive urban developments, the mall culture has seamlessly integrated into the everyday lifestyle of consumers in Kolkata. By fostering social inclusion, shopping malls offer diverse commercial and economic opportunities and entertainment facilities to the consumers, while contributing to an enhanced socio-cultural quality of urban life. This dynamic interplay contributes to a holistic comprehension of social sustainability. The present research delves into the concept of social sustainability with respect to the built environment like predominant shopping malls in Kolkata. The paper involves literature study encompassing an extensive review of various references to acquire qualitative data and insights into the numerous facets of social sustainability as highlighted by various theorists. A framework delineating specific aspects related to the preservation of socio-cultural characteristics is subsequently established from questionnaires. The study addresses the challenges arising from potential conflicts among the social sustainability aspects related to shopping malls and their practical implementation in the backdrop of the city's urban fabric. Exploration of these factors potentially provide guidance for future design decisions for the upcoming shopping malls in Kolkata, aiming to foster more socially sustainable communities within the city's urban fabric.

Keywords: Kolkata Retail Landscape; Flourishing shopping malls; Mall Culture; Social Sustainability; Socio-cultural Characteristics and Sustainable Communities.

INTRODUCTION

The rapid pace of urbanization in recent years has culminated in the drastic makeover of the retail sector of Kolkata leading to the emergence of luxurious shopping malls. The advent of these upscale malls in the city, equipped with state-of-the-art facilities, has initiated a shift in consumer purchasing patterns, marked by increased affordability and high level of affluence. These thriving shopping centres, offering a comprehensive experience encompassing shopping, dining, and leisure all under one roof, have been progressively transformed into weekend destinations - a rendezvous to enjoy with relatives and friends in the weekends (Moss, M.H., 2007). With the dawn of this new era in the retail scenario of Kolkata, the mall culture has steadily made its way to the everyday life of the citizens. Propelled by a rapidly expanding economy, demographic shifts, an empowered consumer base and high density of the city, the urban retail is undergoing a transformation to align with global standards and buyer preferences. This transition has evolved from traditional markets to the luxuriously designed outlets modified with present day amenities to achieve the essential comfort and customer satisfaction level creating positive influence on the shoppers. The increasing number of multi-storied malls in Kolkata has taken a constructive role that extends beyond being just commercial spaces. They foster social interaction, provide convenient access to various facilities and entertainment, create new opportunities for spending leisure time thereby contributing to an enhanced socio-cultural quality of urban life. With features like multiplexes, gaming zones, food plazas, and ambient coffee shops, these malls have redefined the traditional perception of urban leisure serving as a retreat from the stresses of the busy, everyday routine, playing a pivotal role in reshaping social sustainability by encouraging social interaction. However, this transformation raises concerns about the potential to compromise the socio-cultural values of the citizens in this era of globalization (Aboutorabi, M., 2018). In between this evolution of the built environment, somewhere down the line, people have lost touch with their cultural roots and heritage - the very core of their existence. The current research explores the concept of social sustainability, investigating its diverse facets concerning the built environment, particularly focusing on prominent shopping malls in Kolkata. The study places emphasis on the preservation of significant socio-cultural characteristics and explores the challenges stemming from potential conflicts among various aspects of social sustainability with respect to shopping malls in the context of the city's urban fabric and the present mall culture. Further investigation seeks to determine whether factors such as ethnic background or the inherent nature of a society contributes to shaping the perception of socio-cultural characteristics, ultimately influencing social cohesion. This study gives directions for future design decisions of the upcoming shopping malls in Kolkata which can be geared towards cultivating more socially sustainable communities within the city's urban fabric.

LITERATURE REVIEW

Built-Environment and the public realm:

Urban built environment has been shaped by social interaction and participation throughout the process of urbanization particularly pertaining to the public spaces in the urban landscape. Public spaces have organically evolved to accommodate large gatherings for various purposes such as listening to leaders, attending sermons, hosting weekly markets, and providing spaces for leisure and recreation. In ancient times, shopping also took place in open spaces alongside other civic activities, resembling the ancient Greek Agora or Roman Forum. However, over centuries, enclosed shopping malls emerged, introducing a separation between urban life and the act of shopping (Ergun Kocaili, B. 2010). These spaces can be viewed as reflections of the dynamic urban process including the social, cultural, and economic factors that truly defines the livability of the city. In pre-colonial Kolkata, prominent areas that were transformed into public spaces comprised the "ghats," "chandimandaps," temple courtyards, fairs, traditional bazaars, and weekly markets known as "haats," among others (Ray, U. 2019). These public spaces, being influenced by the colonial ideals, drew inspiration from the neighborhood or "para" culture characterized by frequent literary gatherings and community football games, among other activities (Dasgupta, S., & Tyagi, M. 2021). Over the years, Kolkata, known for its rich and diverse cultural amalgamation, has adapted to various transformations and has welcomed and incorporated these changes into its urban character. The progression of contemporary shopping malls into public spaces traces its roots through this historical journey (Benjamin, W., and Benjamin, W.W., 1999). Simultaneously, the city aspires to match the vibrancy and grandeur of global cities by incorporating Western concepts into its shopping malls, catering to the demands of contemporary lifestyles (Choudhury, D., 2017). The prevailing socio-cultural influence that once defined informal neighborhoods and middle-class clusters, known as "paras," characterized by regular gatherings in the open verandas or rowaks, tea stalls, local clubs and serving as nurturing grounds of art and literature (Dasgupta, S., & Tyagi, M. 2021) is diminishing as Kolkata undergoes metamorphosis in its socio-economic landscape. The emergence of modern housing complexes, thriving malls, and high-rise apartments is reshaping the urban fabric of the city (Sen, D., 2011).

Kolkata - The Urban Context:

Situated on the east bank of the River Hooghly, Kolkata has experienced development along the river in scattered patches that extend outwards from the central core. The city has evolved by embracing its past and demonstrating a dynamic willingness to adapt to the changes. Public spaces like marketplaces in Kolkata have been serving as gathering spots where people naturally assembled which in turn became an integral part of the daily life of the citizens. These spaces still continue to dominate the city's urban framework, playing a paramount role in preserving its resilient spirit and identity (Choudhury, D., 2017). Against the backdrop of rapid economic growth and elevated living standards, the shopping malls in Kolkata are undergoing transformations to align with the evolving shopping behavior of the customers. This change is influenced by a shift in the mindset of customers, impacting their preferences for purchase, satisfaction levels, and awareness criteria (Kumbharjuvenkar, R.V., 2018). These public spaces, being visible in the expression of the urban built environment play a significant role in shaping a cohesive urban society, by embodying the cultural and ethical identities. Thus, public spaces and urban culture are intricately linked offering a framework for examining the trajectory of urban transitions the city has experienced. The shopping malls prioritizing customer comfort and providing a respite from the bustling urban environment have been instrumental in shaping Kolkata's urban landscape thereby playing a vital role in upholding the city's vibrant character. However, they lack the personal warmth and human touch found in traditional settings. Thus, there is an urgent need for creative thinking to preserve the essence of the city amidst these dynamic changes outlining a future development trajectory aimed at perceiving social sustainability.

Social sustainability:

The design of shopping malls and the incorporation of modern technology to enhance customer satisfaction and comfort thus stimulating business growth play a crucial role in the foundation of sustainable future of urban retail with major impacts in the quality of life of the people and their bonding with the cities. Contemporary shopping malls have the potential to integrate social, economic, and environmental parameters, aligning with the objectives of sustainable development and thereby attracting prospective shoppers. Sustainability represents a comprehensive approach that influences urban forms, fostering new social behaviors. Social sustainability, as one of the three pillars alongside economic and environmental sustainability, centers on enhancing the well-being of communities and societies. In addition to fostering social inclusion, shopping malls offer various commercial and economic opportunities to the society, accompanied by challenges that directly impact the lives of individuals within the community. This dynamic interaction contributes to a comprehensive understanding of social sustainability (Han. H et. al., 2019).

Kolkata - Socio-cultural transformation

The post-colonial city of Kolkata, facing the immense pressure of rapid urbanization, has become an exemplar of cultural diversification. It showcases a unique blend of both eastern and western influences, incorporating new urban forms that gradually alter the city's fabric and socio-cultural character (Satpati, L.N., 2022). The emerging neighborhoods in Kolkata, marked by their exclusive and introvert character, play a role in diminishing cohesiveness by discouraging social interactions. The influx of multi-storied apartments and complexes, replacing stand-alone middle-class homes, has systematically eliminated points of interaction and social mingling with the gradual disappearance of the “para” culture. This transformation has led to a significant reduction in the cultural significance that traditional "adda" zones, such as those in 'rowaks' or tea stalls, once held in the society promoting social bonds and fostering the Bengali intelligentsia. People, today, have somewhat shifted their leisure and recreational activities from traditional venues like parks, playgrounds, and theaters to shopping malls lured by the variety, grandeur and comfort offered. This has resulted in a gradual decline of social gatherings, traditional community bonds and cultural practices which were once the foundation of the society deeply rooted in the city's history(Bloch. P.H., et. al.,1991).

METHOD

The proposed research will involve inspecting the ways in which public spaces have impacted the social interactions, cultural practices, and community dynamics amid the emergence of recent trend of mall culture in Kolkata. Primary information is documented through field studies, surveys and interviews for understanding the character of the changing socio-dynamics of the city. These surveys posed qualitative insights and also focus on the factors like understanding of the gradual waning of the unique socio-cultural environment in the neighborhoods of Kolkata and the potential concerns arising from the shift in public space dynamics. The paper will also involve case studies of the traditional and contemporary public spaces to understand the evolution of new spatial arrangements catering to the current priorities like vehicular access, technological advancements, lifestyle preferences, while addressing traditional needs such as inclusive access and identity creation through design principles. By exploring the balance between current necessities and cultural identity, the research aims to contribute valuable insights into the ongoing metamorphosis of public spaces in Kolkata through a comprehensive framework of questionnaires and interviews. The questionnaire, designed to capture a wide range of variables, serves as a structured tool for collecting quantitative data encompassing socio-cultural practices, demographic makeup, and perceptions of respondents. Additionally, interviews provide a qualitative dimension to the research, allowing for in-depth exploration of individual experiences and perspectives. Utilizing secondary data from relevant literature and research papers, amendments in urban governance and planning policies this research comprehensively explores the transition of the evolving public spaces in the city and the consequent impact on the socio-cultural framework.

Experiment and results

The evolution of the shopping phenomenon has undergone a profound transformation, starting from the barter system and progressing through various stages, including markets, shops, and stores. This evolution has been significantly shaped by a confluence of social, economic, and technological advancements throughout the centuries. Literature study reveals that throughout history, the shopping phenomenon often integrated with other civic functions, became a focal point for civic and social activities. It was not just a place for transactions but also a space where communities converged, exchanged ideas, and celebrated cultural events. This shared use of open public spaces for shopping and communal activities created a sense of belonging and community identity and contributed to influence the city's overall image (Ergun Kocaili, B. 2010). Over time, with the advent of urban development, shopping dynamics have undergone significant changes. The emergence of enclosed shopping spaces and climate-controlled environment, such as departmental stores and shopping malls, marked a departure from the traditional open markets. The survey conducted in Kolkata, recognizing its predominantly urban landscape, employed a structured questionnaire spanning three generations. The questionnaire was divided into two parts to comprehensively gather information. The first part of the survey focused on collecting details related to the demographic characteristics of the respondents and the second part focused on their attitudes, behaviors, perception and shopping motivations in the context of Kolkata's urban environment and the social sustainability. Based on the survey results, a key insight is that shopping has emerged as the most coveted activity of the citizens. Additionally, the findings reflect that shopping malls have become a preferred destination, particularly during weekends, for a specific age group. These findings are indicative of the evolving dynamics of consumer preferences, leisure activities, and social behaviors in the urban context of Kolkata. The emphasis on shopping, especially within the mall environment, reflects the changing lifestyle patterns and leisure choices. This information can be valuable for businesses, urban planners, and policymakers seeking to understand the evolving needs and preferences of the citizens of Kolkata. The case study of City Centre I in Kolkata identifies it as an ideal destination featuring modern outlets tailored to meet the present demands of the citizens along with a traditional feature-the stepped plaza at the center, a unique spot where the shoppers can spend hours, contributing to social cohesion. The inclusive and diverse nature of City Centre, Salt Lake makes it a place that captures the true spirit of Kolkata, particularly the passion for 'adda'—an inherent cultural practice in the city. Overall, this case study identifies City Centre I as a dynamic and culturally resonant space that not only caters to the shopping needs of Kolkata's residents but also serves as a social hub reflecting the city's spirit and cultural identity with a blend of traditional and contemporary environment. The complex dynamic interplay between social sustainability and urban fabric is crucial for developing strategies and identifying spatial layout and architectural features that foster inclusive and socially cohesive urban environments in the context of shopping malls. This connection goes beyond the utilitarian and commercial aspects of shopping and emphasizes the role of the malls as a social hub within the urban landscape.

CONCLUSION

In the contemporary era, the concept of shopping has undergone a substantial shift. The shopping mall is portrayed as more than just a commercial space - a place that facilitates social interactions, community engagement, and a sense of belonging to the city. While this shift from traditional retail formats to modern malls provides a comprehensive solution for various consumer demands in today's fast-paced life, it raises concerns about potential impacts on the socio-cultural values of the citizens. Balancing the traditional and modern design principles in these shopping malls becomes essential to protect the city's indomitable cultural character while embracing contemporary conveniences. The paper calls for a balanced approach evolving to meet the needs of the present while respecting and preserving the traditional socio-cultural values that hold significance for the citizens. The key lies in creating an environment that seamlessly blends the convenience of modern amenities with the richness of traditional cultural identity. In essence, the concept of a sociable connection underscores the role of the mall as a dynamic and inclusive space that fosters social sustainability and vibrancy of the city. The study aims to inspire urban designers to integrate spatial features that not only cater to commercial aspects but also stimulate social cohesion. The aim is to revive a nostalgic feeling, thereby augmenting the lost socio-cultural ethics and projecting the true image of the city.

CONFLICT OF INTEREST

We the authors of this paper express no conflict of interest.

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Resilience in Safety and Security in Urban Parks Through Defensible Landscape Architecture Approach

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Abstract— Urban parks are vulnerable to criminal activities, with a significant portion of the affected population lacking awareness of the correlation between crime and the built environment. Despite being vital components of urban life, these green spaces are often overlooked in discussions surrounding crime prevention and public safety. This paper focuses on the investigation of the susceptibility of urban parks to criminal activities, shedding light on a critical aspect of the city's social fabric wherein the assessment of the employed design strategies plays a vital role.

A research methodology has been developed leading to the formulation of a comprehensive framework of design strategies that can be instrumental in reducing the safety and security issues in urban parks, consequently reducing associated crime rates. The methodology relies on an extensive analysis of secondary data from various relevant sources including reports, journals, research papers, and case studies providing various perspectives, insights, and quantitative data on current crime rates specific to urban parks. It also highlights the crucial connection between the creation of aesthetically pleasing environments and their impact on safety. Further, user experience and perception are the key aspects of this research, wherein inputs have been gathered from numerous concerned respondents of various age groups. The analysis employs Crime Prevention Through Environmental Design (CPTED) principles, focusing on natural surveillance, access control, territorial reinforcement, and maintenance.

The findings reveal a gap in the current design strategies for urban parks, particularly in addressing open-park security, wherein the effectiveness of landscape components and defensive techniques at various security levels within urban parks has been underlined. It is imperative that by understanding the symbiotic relationship between landscape design and safety components, the study recommends an indispensable harmony to not only reduce crime but also preserve the intrinsic essence of the surrounding environment.

Keywords: Resilience, Defensible Landscape, Crime Prevention, Urban Park

INTRODUCTION

The urban parks of New Delhi are important public spaces that provide numerous benefits to its residents. However, these spaces are often vulnerable to crime, vandalism, and other forms of antisocial behavior. In recent years, there has been an increasing emphasis on the use of defensible strategies in landscape architecture to create safe and secure public spaces. Defensible space is a concept developed by Oscar Newman in the 1970s, which emphasizes the need to design spaces that can be easily defended by their users. It emphasizes the need to create spaces that are easily defensible for their users. Defensible space is achieved through a combination of physical and social design strategies that create a sense of ownership and control among the users of a space. These strategies can be used in landscape architecture to create safe and secure urban parks.

A study conducted by the Indian National Crime Records Bureau (NCRB) in 2019 underlined that parks were one of the top five locations for crimes against women in Delhi. In Bangalore, a survey conducted in 2018 found that 57% of women felt unsafe in public parks. Ensuring safety and security for individuals in public open spaces is of utmost importance. Various theories have been proposed regarding the relationship between the built environment and feelings of insecurity (Hakeem & Kumar, 2012), while studies have also shown that social characteristics, such as community cohesion and homogeneity, play a significant role in explaining crime and fear. (Banerjee, 2001) have identified park features, neighborhood demographics, and social cohesion as factors that account for differences in crime rates in parks. Additionally, a study conducted in urban greenways in Japan found that fear of crime was higher in areas with fewer people, restricted paths, and abundant vegetation (Rajput, 2016) (Chatterjee, 2014).

Research has also shown that parks are less popular when perceived as settings for undesirable activities such as drinking, drug use, crime, teenage hangouts, homelessness, and rowdy behavior, which can lead to clashes with rangers. Furthermore, studies by (Garau, 2015) have indicated that certain park users, including drug addicts and loiterers, can contribute to an increase in crime rates, vandalism, and male sexual violence against women. (Gohain, 2017), in his research on 'Importance of Safety in Public Parks for Crime Prevention' highlights the importance of parking security in preventing crime in public parks, while (Iqbal, 2021) in the chapter, 'Inclusive, Safe and Resilient Public Spaces: Gateway to Sustainable Cities?' suggests introducing new activities that encourage mixed land use and create a flow of people at different times of the day to promote inclusive, safe, and resilient public spaces in India.

Despite extensive research, there are gaps in understanding the effectiveness and sustainability of defensible strategies in landscape architecture. There's a need for further investigation into integrated approaches, considering social and cultural influences, especially in developing countries like New Delhi. The economic and environmental sustainability of these strategies also require attention. This paper analyzes factors influencing urban park success and recommends crime reduction options based on CPTED guidelines.

Study Area

Delhi, the National Capital Territory (NCT), India, with over 18 million people is the fifth most populous as well as one of the most unsafe cities in the world (National Institute of Urban Affairs, 2016). According to a report by the Delhi Development Authority in 2020, there are more than 18,000 parks and gardens in the NCT spread over about 8,000 hectares in various locations According to a survey conducted in 2020 from 24,301 respondents on 'State of Policing Law and Order in New Delhi', 60% of the public feel that open spaces of the city are not safe for women, children, and senior citizens, out of which 67% respondents are from South Delhi. The NCRB also reported 3,770 cases of juveniles being kidnapped in Delhi, the most among all metropolitan locations (Phadke, 2016). Delhi had 1,231 reported incidents of rape in 2020, the highest among the 19 Indian cities according to the NCRB.

METHODOLOGY

Park design literature was reviewed, and a field study with 155 users was conducted in New Delhi to improve safety and design, using CPTED guidelines. The survey aimed to assess landscape design's impact on safety, aiding designers and the community in identifying measures to enhance park safety and usage.

The assessment aims to evaluate the park's conditions and suggest CPTED measures focusing on natural surveillance, access control, territorial reinforcement, and maintenance. Involving community collaboration ensures fair and effective results, identifying improvement needs and proposing guidelines to enhance park safety and usage based on community input.

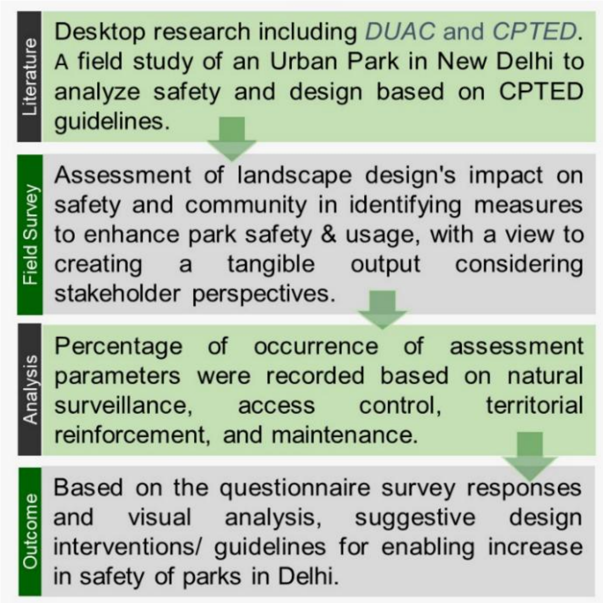

Figure 1 : Methodology

CASE STUDY

Aastha Kunj Park, nestled in Nehru Place, New Delhi, amidst revered landmarks like Kalkaji Temple and Lotus Temple, spans 200 acres, managed by the Delhi Development Authority (DDA). Despite its vast expanse, the park grapples with security issues like theft and snatching due to inadequate lighting, scalable walls, and a lack of security personnel. Residents, alarmed by rising crime rates, formed their security squad to patrol access points. The park's expansive nature poses challenges in maintaining security. The community's proactive involvement highlights the urgent need to address safety concerns and restore Aastha Kunj Park as a secure and inviting urban sanctuary.

Observations

The park, open from 5:00 a.m. to 7:00 p.m. with six gates (one closed), suffers from various safety and security concerns despite having three direct connections to a neighboring community. With only 87 staff and no on-site guards, nighttime security relies solely on two to three police officers. However, inadequate signage, lack of lighting on auxiliary paths, and open defecation by slum residents make navigating the park challenging and unsafe, especially after dark. Further concerns include overflowing garbage near Gate No. 2 due to hawkers, compromised natural surveillance in areas surrounding Sant Nagar, missing safety barriers around water bodies, and inconvenient stone walkways. Additionally, dried-up, or polluted waterbodies pose a health risk through potential waterborne infections. These issues collectively contribute to a deserted park environment in the evenings, discouraging usage and further exacerbating security concerns.

Figure 2 : Architecture of the System

Analysis and findings

The questionnaire methodology based on CPTED has been developed for the four categories (i.e., Natural Surveillance, Natural Access Control, Territorial Reinforcement, and Maintenance), wherein the response to each question is summarized.

Figure 3(a) : Site Image

Figure 3(b) : Site Image

Figure 4 : Site Plan (demarcation of the gates)

Table 1. Findings based on CPTED questionnaire for the category of Natural Surveillance

Target Question	Response
What is the land use in the quick area of the recreation area?	Aastha Kunj Park in Nehru Place connects affluent and underprivileged settlements, including Greater Kailash and Garhi Village, surrounded by tourist and religious sites. Maintained by DDA.
Is the park near any houses?	One complete side of the park is adjacent to residential land use,and the homes face the park, providing direct or indirect monitoring.
Is it conceivable to see what's happening inside the park from outside?	Locations with high contours and larger rock settings from theoutside lack good visibility for any action.
Is it conceivable to hold locate sight lines across the park?	Park entrances are hidden, with numerous hiding and ambush spots like valley lines, dark passages, bends, rocky outcrops, and under metro pillars
Is there any planting along courses,close to offices, or close to movement regions that makes spaces of camouflage or squares perceivability?	While the landscape does not obstruct vision near activity areas orshared utilities, it hinders visibility from the periphery and corners. Also, very less activities are currently in the park.
Is there adequate lighting around evening time at passage focuses, strolling trails, and movement regions? Is there glare from the lights?	Moreover, the park's lighting is inadequate, and some of the lights do not work/broken.

Table 2. Findings based on CPTED questionnaire for the category of Natural Access Control

Target Question	Response
Is it possible to tell where the park's entrances are from the outside?	Because of the lack of signs, entrances/exits, flanking the main road adjoining residential/commercial land uses are more difficultto locate.
Is it possible to see the park exits from within the park?	It is difficult to locate entry/exits for non-frequent users.
Is the park's layout simple to comprehend?	The layout is simple to comprehend.
Is there satisfactory signage to leadguests to stop doorways, exits, and center focuses?	Only applies to important entrances and exits near the main route.
Is there any lighting that coordinates guests between park areas around evening time?	When it's dark, the Park isn't properly illuminated, leaving it particularly vulnerable to illicit activity.

Table 3. Findings based on CPTED questionnaire for the category of Territorial Reinforcement

Target Question	Response
Are the park's boundaries and entrance locations well-defined?	The Park border line is well marked along with the entry points in sections next to the main road,
Is there a sign at the park that lists the park's rules?	Near the main road entrances, there are two of them.

Table 4 . Findings based on CPTED questionnaire for the category of Maintenance.

Target Question	Response
Is the park's landscaping in goodcondition? Is there any landscaping that ishigher than two feet above the ground?	Trees are usually planted near active areas, but some near neglected private properties have low canopy and large planting.
Are the lights in good functioning order?	No, not all of the lights are operational. During the night, the Park becomes dreary and dismal.
Is there any trash or garbage in the park?	Yes, at most edges that look inside (acute angles) and behind higher levels (contours)
Is there any evidence of graffiti or vandalism?	Minimum vandalism is observed at small built structures.
Is there a maintenance schedule for the park?	According to park authorities, they have a 45-day park maintenance strategy in place, as well as specific measures for the holidays.

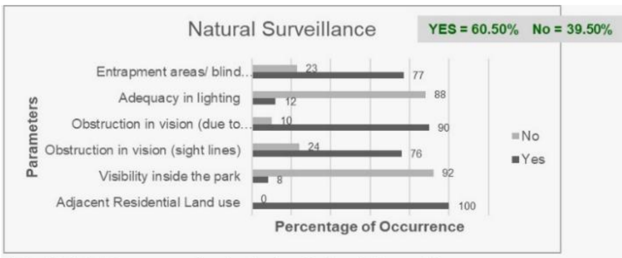

Fig 13 (a). Response Analysis for Natural Surveillance

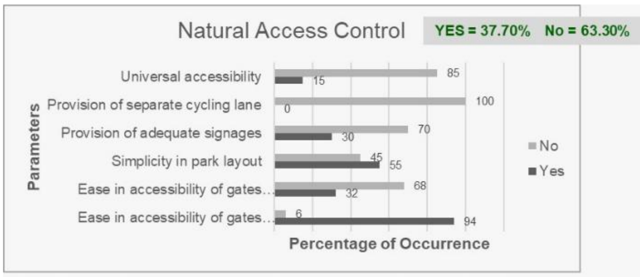

Fig 13 (b). Response Analysis for Natural Access Control

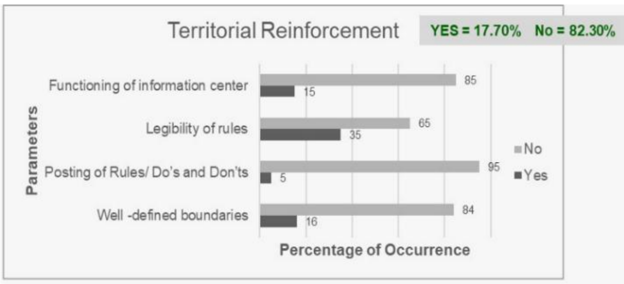

Fig 13 (c). Response Analysis for Territorial Reinforcement

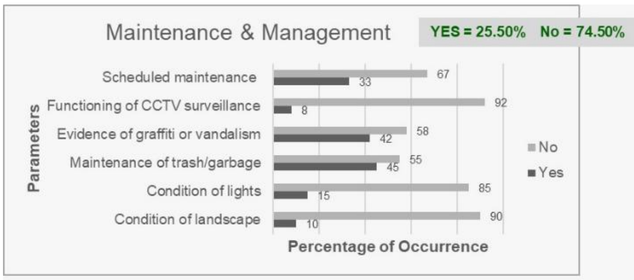

Fig 13 (d). Response Analysis for Maintenance & Management

Figure 5(a), (b), (c), (d) : Response Analysis

Proposed strategies

Based on the case study analysis and questionnaire survey responses following strategies can be proposed:

Natural observation and sight lines

When designing urban parks, ensuring visitor safety is paramount. Firstly, visibility of children's play areas from adjacent roads facilitates parental supervision, reducing risks of accidents or abductions. Secondly, park edges overlooking residential or commercial developments serve as a natural surveillance mechanism, deterring criminal activities.

Entrapment regions

To safeguard park visitors, design elements must be considered. Firstly, avoiding entrapment zones along walkways reduces vulnerability to crime. Secondly, pathways bordered by low-lying or high-branching vegetation prevent entrapment and enhance sightlines. Thirdly, multiple entrances and exits facilitate easy access and flow of people, enhancing emergency response during incidents.

Clustering and programming for a range of activities

Activity zones can be clustered or arranged to offer a variety of activities, encouraging visitors to spend more time in the park and monitor the area. Additionally, space for street activities attracts diverse groups and creates a lively atmosphere. Monitored washrooms provide convenience and safety for visitors.

Location of activity generators

Well-designed parks should include features that attract visitors and promote usage. Incorporating amenities such as food kiosks and information centers near playgrounds increases visibility and attractiveness. Outdoor cafes and restaurants are encouraged as park-related activity generators. Additionally, amenities should be located near park boundaries, along thoroughfares, or connected to frequently used pedestrian paths to prevent isolation.

Night-time use

Encouraging Park use at night requires well-lit spaces visible from adjacent roads or housing developments. Night-time activities should be located away from potential entrapment zones to ensure safety. Proper lighting deters crime and creates a sense of security, with illumination directed away from residential areas to minimize disturbance.

Signs and information

Creating a safe and enjoyable park experience requires thoughtful planning and design, including signage. Clearly marking frequently used areas aids navigation, while signs at intersections provide crucial information and emergency assistance guidance. Adequate lighting on pathways prevents accidents, with signage indicating emergency phone locations for quick access during incidents.

Lighting

Lighting is crucial for creating safe and accessible public spaces, especially at night. Pathways and night-time areas should be lit to prevent accidents, increase visibility, and create a sense of security. Proper boundary delineation separates night-time areas from those not intended for use, with landscaping elements positioned appropriately to avoid obstructing light sources.

Optimization and linkages

Parks and open spaces play a vital role in urban environments, providing benefits such as promoting physical activity and enhancing the city's aesthetic appeal. Refurbishing parks to provide access from populated areas increases their use, with clear pathways and signage guiding visitors. Integration with sidewalk systems creates inviting spaces for pedestrian interaction.

Maintenance

Maintaining a clean and well-maintained environment is critical for public spaces. Regular monitoring ensures cleanliness and litter-free areas, with measures taken to prevent graffiti and vandalism. Replacing vandalized or faulty bulbs is a priority to maintain adequate lighting levels.

Social and Cultural Factors

Cultural values and norms influence people's perception of safety and security in public spaces. Tailoring defensible strategies to specific contexts, reflecting cultural preferences, and engaging with local communities fosters trust and relevance. Incorporating local knowledge into design processes ensures strategies resonate with community norms, enhancing park safety and social cohesion.

CONCLUSION

Implementing the recommended design strategies in urban parks can help reduce crime and fear of crime by creating a safer and more inviting environment for visitors. By ensuring natural observation and clear sightlines, potential offenders are less likely to feel that they can conceal themselves or their actions. Multiple entrances and exits and the avoidance of entrapment zones also make it harder for offenders to carry out crimes without being noticed. Well-lit areas with clear signage and amenities make it easier for visitors to navigate the park and find help if needed. Additionally, the clustering of activity zones and the interaction with the sidewalk system encourage greater use of the park, increasing natural surveillance and reducing the likelihood of criminal activity. Regular maintenance also helps to ensure that the park remains a safe and enjoyable environment for visitors, deterring offenders from targeting the area.

The study highlights the importance of considering a range of factors when designing and managing urban parks, including the use of defensible design strategies, social and cultural factors, economic and environmental sustainability, and regular maintenance. Engaging communities in the research process can provide valuable insights into the social and cultural factors that may influence the effectiveness and adaptability of defensible strategies. This can help ensure that defensible strategies are designed and implemented in ways that meet the needs of the community.

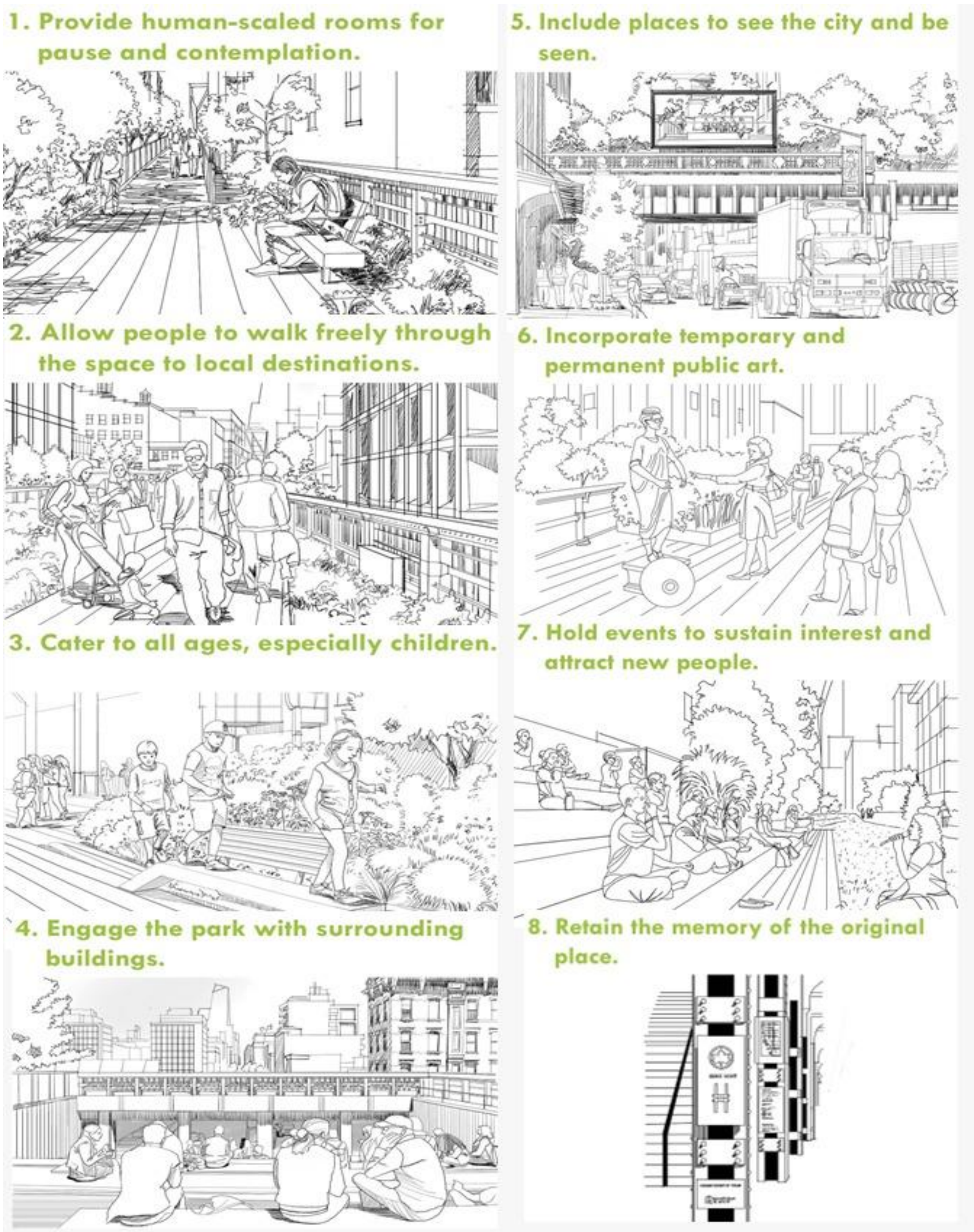

Figure 6 : Eight ways to build a better Urban Park.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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A Study of Architectural Evolution of Houses in Shillong: Analyzation of structural& architectural features of houses

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Abstract— Nestled among the picturesque hills of Meghalaya, Shillong has witnessed a captivating journey in its architectural landscape. This research paper unveils the fascinating tale of Shillong's houses, evolving from the traditional Khasi dwellings, transitioning through the colonial-era Assam-type structures, to the modern homes that grace its hills today. Shillong, a gem in India's northeast, is a city of natural splendors. Imagine lush greenery, moderate weather, and a cultural vibrancy that mirrors the diverse fabric of its people. At the heart of this beauty lie the traditional Khasi houses, gracefully curved like overturned boats, reflecting a harmonious blend of shelter and nature. Resilient and earthquake-resistant, these homes embody the age-old wisdom of the Khasi people, rooted in a deep connection with their surroundings. The colonial era brought winds of change, especially after the seismic shake-up of 1897. In response, Assam-type houses with wooden frames and floors became part of Shillong's narrative. Guided by a Japanese architect's vision, this marked a departure from tradition, weaving colonial influences into the city's architectural fabric. Fast forward to today, and Shillong's skyline is a harmonious blend of tradition and modernity. The houses tell a contemporary tale, embracing technology and sustainability. From sleek, modern designs to eco-friendly structures, Shillong's homes now echo the aspirations and dynamism of its residents. This research peels back the layers of time, unveiling Shillong's architectural evolution. From the cultural embrace of Khasi houses to the assimilation of Assam-type structures during the colonial period and, finally, to the modern homes that dot the hills today, each phase reflects not just a change in design but a story of Shillong's spirit and how it has evolved over the period. Through this exploration, the research sheds light on the dynamic interplay between architecture, history, and culture, offering a glimpse into the ever-changing identity of Shillong as mirrored in its homes.

Keywords: Khasi houses; Shillong; Traditional construction; Assam type houses; Structural and Architectural Features of Assam type houses; Materials; Modern houses

INTRODUCTION

The research paper titled "The Enduring Legacy of Traditional Khasi Houses in Shillong: A Study of Architectural Evolution" embarks on a compelling exploration of Shillong's architectural metamorphosis, tracing its roots from traditional Khasi dwellings through the assimilation of Assam-type structures to the contemporary homes that define its skyline today. Shillong, nestled in the scenic hills of Meghalaya, unfolds as a city boasting natural splendor, cultural richness, and a captivating history etched into the design of its homes.

This study unravels the captivating tale of Shillong's houses, showcasing the graceful evolution from the iconic oval-shaped Khasi houses, resembling overturned boats, to the introduction of Assam-type structures influenced by colonial forces. The narrative extends to the present, revealing a harmonious fusion of tradition and modernity in Shillong's architectural landscape. The homes, reflecting the aspirations and dynamism of its residents, stand as testaments to the city's ever-changing identity.

METHODOLOGY

The methodology employed in this study primarily relies on secondary data collection from diverse sources. Extensive literature reviews, academic publications, historical records, and architectural studies form the foundation of the research. The exploration of traditional Khasi houses involves a detailed examination of historical and cultural contexts, architectural features, and current statuses.

Multiple sources, including works by local experts and researchers, contribute to unraveling the intricacies of these traditional dwellings.

Similarly, the examination of Assam-type houses involves delving into historical records, government documents, and architectural analyses. Insights from the post-1897 earthquake rebuilding efforts, the influence of a Japanese architect, and the subsequent evolution of Shillong's housing structures are pieced together from various reputable sources.

AIM & OBJECTIVE

The aim of this research is to comprehensively explore and chronicle the architectural evolution of Shillong, unveiling the transition from traditional Khasi dwellings, through the colonial-era Assam-type structures, to the contemporary homes that grace its hills today. This study seeks to unravel the underlying factors and influences that have shaped Shillong's architectural landscape over time.

The main objectives are:

- To examine the historical and cultural context of traditional Khasi houses in Shillong, shedding light on their architectural features and significance.
- To analyze the impact of the colonial-era seismic events of 1897 on Shillong's architectural narrative, particularly the assimilation of Assam-type houses with wooden frames and floors.
- To assess the present state of Shillong's houses, focusing on the contemporary blend of tradition and modernity, including the integration of technology and sustainability.

LITERATURE REVIEW

General Description of Traditional Khasi Houses in Shillong

The traditional houses of Shillong and the surrounding areas are essentially oval or egg-shaped, resembling an overturned boat. The resemblance to an egg is explained by some locals through the traditional belief that an egg symbolizes the source of life. According to this belief, the eggshell serves as protection for the contents of the egg, much like how the traditional houses provide protection for their occupants. The building layouts, depicted in Figure 1, typically involve structures erected on elevated platforms. Thatch is commonly used for roofing, while the walls may vary in construction materials—ranging from stone masonry with lime mortars to lime-rendered mud walls or thatch—depending on prevailing weather conditions. In regions experiencing heavy rainfall, mud and stone walls are preferred, as thatch tends to deteriorate rapidly under such conditions. Figure 2 provides a side view of a typical traditional Khasi building with grass walls and thatched roofing, while Figure 3 displays the front view. Figure 4 showcases an upgraded traditional house featuring lime-rendered mud walls and corrugated iron roofing sheets.

The construction of the Iing Sad, the residence of the queen mother and custodian of the matrilineal culture of the traditional Khasi people on the Shillong plateau, adhered to the traditional Khasi building system. Despite being constructed with modern building practices and professional supervision, the building replicates the methods, materials, and structural forms employed in traditional constructions, as depicted in Figure 5. In this study, the Iing Sad was frequently used to illustrate the structural form of the traditional Khasi construction system.

The initial section of the house comprises the roofed entrance, serving as the gateway to the dwelling. Progressing from the entrance leads to the Shyngkup, functioning akin to a verandah that acts as a buffer between the main living spaces and the external environment. The concluding part of the house is the Shah Ksew (first plank), positioned at the terminus of the Shyngkup. Beyond this point is reserved exclusively for human habitation, and it marks the boundary where domestic animals, including dogs, are restricted.

In alignment with the Shah Ksew, approximately halfway along the wall, stands the Rishot Blei—a column with religious significance rather than structural purpose. This column is observable in the frontal section of traditional houses, as illustrated in both Figure 1 and Figure 5.

Extending outward from the living area is the Neng Pei, identified by Mawrie [6] as the outermost segment of the house accessible to strangers. Beyond the Neng Pei lies the Rympei, constituting the innermost portion of the dwelling and serving as the private family space. This area is where the family engages in worship, and it also serves as the repository for oral histories and cultural traditions passed down through generations.The sleeping quarters, referred to as Iing Kyndong, are established within the structure. Notably, a small window opening known as Pongshai is typically incorporated on one side of the building.Due to the elevated precipitation in the region, houses are typically elevated on short columns. This elevation serves to enhance the aeration of the supporting wooden elements, mitigating decay, and preventing rodents

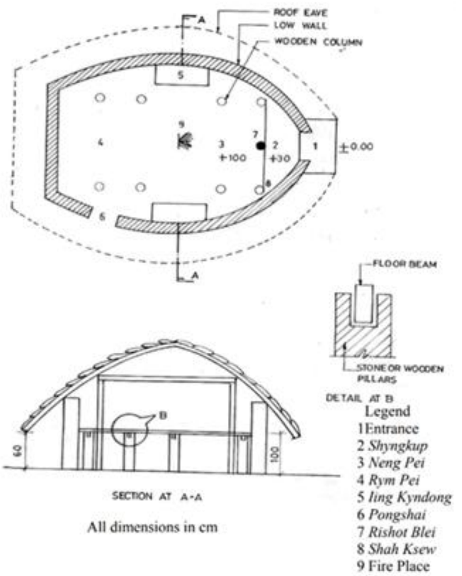

Figure 1 : Layout of traditional Khasi House

Figure 2: Side View

Figure 3: Front View

Figure 4: An upgraded traditional khasi house

Figure 5: The Ling Sad

from easily infiltrating buildings. Despite Gurdon [2] characterizing traditional houses as inferior to those constructed by newly converted Christians, emphasizing the latter's superior elegance and planning, the performance of these buildings during the 1897 Shillong earthquake contradicted such claims. Gurdon's opinions seem to have been influenced more by aesthetic and sociological considerations than structural ones

After completing the foundation, owners gather bamboos and dried grass for construction, emphasizing the importance of using high-quality materials for a durable structure. The Khasis, known for their precision, calculate the optimal time and month to gather timber, a crucial step to ensure it remains free from pests that could compromise its quality.

Timber gathering typically occurs from November to January, aligning with the winter season. Alternatively, if necessary, the process can take place on any day of the month under the crescent moon, as its dim light deters insects. This practice, rooted in a generational myth, ensures the wood's superior quality. The special night with reduced moonlight occurs only once a month. Following this, the timber is left exposed to the sun for about a month to dry and lighten, a process akin to curing, primarily for ease of transportation.

Transportation is scheduled for March and April, during the springtime when people are generally free from their daily obligations.

In some instances, collected wood undergoes an additional step: boiling in extremely hot water to eliminate any termites residing inside before the drying process.

With these preparations complete, construction begins with the erection of 2ft high stone pillars. Further details of the construction process will be explained in subsequent sections as the topic progresses.

History of Assam Type Houses in Shillong

In February 1874, Shillong started functioning as the capital of newly built Assam province. However, it was not equipped with modern amenities. Prior to 1897, most of the public offices and private houses of Shillong were built of roughly hewn masonry. The disastrous earthquake of 1897 (June 12), reduced them in a heap of ruins in a space of few seconds. After that unfortunate event, the town was rebuilt, on the advice of a Japanese architect – the buildings were all light structures built on wooden frames and floors, popularly known as the 'Assam type house'. Before that, there was no practice of wooden floored house

The old Assembly house was constructed by the expert engineers and architects, following the Assam type house with wooden frames and floors. So, it clearly proves that the Assembly building, was constructed after the disastrous earthquake of 1897, according to the new rules of construction. Before the earthquake, the old Assembly building was situated near the Police Point. It was a waiting place for the bullock and pony carts and these served as the only source of communication for the people of Shillong.

The Government of India Act, 1935, made provisions for a Legislative Assembly in each and every province of India, and accordingly, the Assembly house had to be constructed. Since Shillong was the headquarter of erstwhile undivided Assam, high level conferences of the Chief Commissioner would be held in a big Assam type house, which was then called 'Constitution Building' (situated on the back side of the present Accountant General Office building). There was no existence of any Assembly Building.

In the early 20th century, the first general elections under British Government were held in India; the newly established Assam Legislative Assembly, with 108 members came into action. The requirement of a permanent Assembly house was felt. Going by this, the construction of the Assembly building may have commenced by 1936-37 (approx.).

Structural and Architectural Features of Assam type houses

The interconnection of elements in this housing style, encompassing posts, wall panels, roof trusses, and roofing components, constitutes a crucial aspect. In formal constructions, connections are established through nailing and bolting. Conversely, informal scenarios rely on coir ropes for connection, introducing concerns about the durability of these connection materials and, consequently, the safety of the dwelling.

Connecting vertical intermediate posts with roofing elements involves the utilization of horizontal wooden scants at different levels—floor, sill, lintel, and eaves. Nails, steel clamps, and bolts secure these connections. Figure 6 illustrates the connection between the main vertical posts and other wooden frame and roof truss members, achieved through a combination of nails, bolts, and steel clamps. Intermediate rafters support wooden planks used for slabs, and these, in turn, are supported on main wooden beams, transferring the load to the primary vertical posts. The attic space between the slab and the roof truss often serves as storage. The truss, constructed from wooden members, supports the roofing material, whether tin or asbestos.

Ikra, a reed growing in marshy land and river beaches, serves as a crucial construction material. The shoot is hollow with nodes at intervals of 150 to 300 mm, featuring a thin but robust skin covered by a heavy and siliceous sheath between internodes. Matured Ikra shoot, best suited for walling or roofing, takes about two years to reach full maturity upon flowering. Ikra reed, rich in starch and cellulose, is less susceptible to insect attacks compared to bamboo. The hollow inner core provides heat resistance, contributing to good thermal insulation. Importantly, Ikra reed does not shrink or flatten during the drying process. Seasoning is achieved through sun-drying for 12 weeks or soaking in water for three days followed by sun drying. Ikra shoot exhibits an excellent bond with mud mortar, lime mortar, or cement mortar.

Two types of Ikra walls are commonly constructed: simple-type and fine-type. In simple-type walls, Ikra reeds are vertically placed outside horizontal battens, with a single Kami lining nailed at 300 mm intervals to confine the Ikra reeds. The gaps between Ikra reeds are maintained at 6 to 15 mm. For fine-type walls, grooves are longitudinally made in the centre of wooden battens, and Ikra reeds, cut to a uniform size, are slipped into these grooves. Kami is fitted into vertical recesses in the battens, with stiffening and tying methods similar to the simple-type.

Typical Assam-type houses feature false ceilings made of timber, bamboo mats, plywood, or AC sheets. This false ceiling, framed with 75x50 mm scants spaced at 600 mm intervals and fixed with nails, creates a cooler environment inside the house and prevents the intrusion of insects from the roof. In some instances, ceilings made of Ikra reed, similar to

Figure 6 : Connection between: (a) posts and horizontal rafters at verandah, (b) posts and horizontal rafters at eaves level, (c) post and ceiling, (d) post, rafters, and inclined roof member at eaves level from inside, (e) post, rafters, and inclined roof member at eaves level from outside, (f) post, rafters and asbestos sheet used for roofing.

Ikra roofs, are observed, especially above covered verandas (refer to Figures 6c and 10).

Framing details of Ikra walls: Regarding the framing details of Ikra walls, this method is traditionally used for cladding, especially in rural areas. It involves placing Ikra reed and/or bamboo matting between wooden frames and plastering the matting with a mixture of cow dung and mud/cement mortar (refer to Figure 8). Preparation of cow dung-mud slurry entails mixing equal volumes of cow dung and soil with sufficient water to create a uniform thin paste. This paste fills the gaps between Ikra reeds and is used for wall plaster. While guidelines suggest adding bitumen and kerosene to the cow dung-mud paste in a 5:1 ratio, this is rarely implemented due to additional costs and labour. Consequently, frequent plaster applications are necessary, particularly after alternating cycles of summer and the rainy season. In some instances, panels are filled with brick masonry walls up to the window sill level. Contemporary adaptations involve filling panels with brick walls, and timber framing is often replaced by thin reinforced concrete columns.

Flooring: Flooring in Assam-type houses varies, with stilted houses often adopting wooden plank flooring and rural areas favoring mud plaster flooring. Elevated floors comprise wood runners (50×100 mm) spaced at about 300 mm intervals spanning between wood beams (120×120 mm) spaced at approximately 600 mm intervals. Common flooring types include cement flooring over an under layer of sand or brick soling.

Roofing: Roofing, a critical component in a region with substantial rainfall, primarily involves pitched CGI sheet roofing over timber trusses (refer to Figure 11a). This roofing style is chosen for its durability in the face of intense rain. In rural areas, Ikra reed is also employed for roofing (refer to Figure 11b)

Figure 7 : Main vertical wooden posts and foundation used in typical Assam-type houses
Reference: Kaushik, Hemant & S., Ravindra. (2012). "Assam-type House"

Modern houses of Shillong

Figure 8 : Details of Ikra walls
Reference: Kaushik, Hemant & S., Ravindra. (2012). "Assam-type House"

Figure 9 : (a) Storage of Ikra reed for further use, and (b) making of Ikra roof and boundary wall.
Reference: Kaushik, Hemant & S., Ravindra. (2012). "Assam-type House"

Figure 10 : Variants of ceiling observed in typical Assam-type houses: (a), (b) wooden ceiling, and (c) ceiling made using Ikra reed and bamboo similar to roofs.
Reference: Kaushik, Hemant & S., Ravindra. (2012). "Assam-type House"

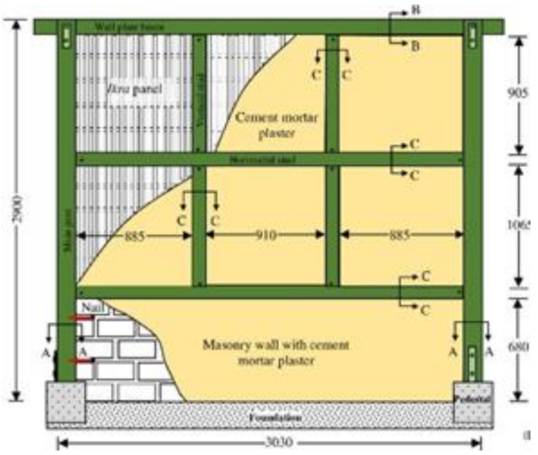

Figure 11: Connection between: (a) posts and horizontal rafters at verandah, (b) posts and horizontal rafters at eaves level, (c) post and ceiling, (d) post, rafters, and inclined roof member at eaves level from inside, (e) post, rafters, and inclined roof member at eaves level from outside, (f) post, rafters and asbestos sheet used for roofing.
Reference: Kaushik, Hemant & S., Ravindra. (2012). "Assam-type House"

In the evolving architectural landscape of Shillong, the contemporary houses gracefully intertwine modern aesthetics with traditional elements borrowed from Assam-type houses. The retention of distinctive features like slanted roofs and expansive open windows pays homage to the rich cultural heritage and practical wisdom embedded in traditional architecture. While modern Shillong houses embrace the use of concrete and other contemporary construction materials for structural integrity and durability, the incorporation of these traditional elements serves multiple purposes. The slanted roofs, for instance, not only nod to Assam's architectural legacy but also efficiently shed rainfall in the region, showcasing a thoughtful blend of tradition and functionality. The large, open windows maintain a connection with nature, allowing ample natural light and ventilation while promoting a seamless indoor-outdoor living experience. This harmonious fusion of modern construction techniques with time-honoured design elements not only preserves cultural identity but also exemplifies the adaptability and resilience of architectural traditions in the face of changing times.

CONCLUSION

The architectural evolution in Shillong, as depicted through the study of traditional Khasi houses and Assam type houses, offers insights into the deep connection between culture, environment, and construction practices. The transition from traditional to modern houses showcases adaptability and resilience, with contemporary structures seamlessly incorporating traditional design elements. The careful selection of construction materials, adherence to cultural practices, and the fusion of modern and traditional features reflect a harmonious coexistence of the past and present. The study underscores the importance of preserving cultural heritage while embracing advancements, emphasizing sustainability, and ensuring the continued relevance of architectural traditions in the face of changing times. Shillong's architectural evolution serves as a testament to the intricate interplay between history, culture, and the built environment

Figure 12: Modern Assam Type House

Figure 13: Modern Assam Type House

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The Science of Temple Geometry

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Abstract— Temples are known and to a greatest extent proven to be a meditative space where people experience a sense of calmness, a medicinal place to cure illness, and so on. Almost every ritual is believed to have a purpose, both in areas of faith and in aspects of physical being. The built form along with these rituals manifests temples as centers of energy, cosmology, health, science, social life, and more. The science of temples developed and evolved over thousands of years of research, subsequently fading into obscurity and neglect. We can experience and obtain the knowledge, intelligence, and power that these structures were built for by understanding the logic and science of Indian temples. The temples were constructed according to precise geometrical specifications given in antient literature. These guidelines are so specific that one must choose to design within the extensive framework which does not allow scope for individual exploration establishing the fact that these structures should be crafted with careful precision. This paper will explore the planning principles of the built form and the extent of the significance of it in relation with the science of these structures.

Keywords: Architecture; Dravidian Temple; Science; Built Environment

INTRODUCTION

The senses are in close contact with the temple structure from walking in with bare feet, and ringing a bell while entering, to entering a dark zone. With this cymatics plays a major role invariably. The body is made up of matter and these matters are partials that vibrate. And temples are known to produce these vibrations through the sounds of the chants, bells, and acoustics of the built form. Vibrations are further broken down into frequencies, which are almost the basis of the existence of matter. Modern science is exploring ways to harness these scientific nodes to elevate the human race, but these were discovered, explored and manipulated in the ancient period, but somehow, due to various social and environmental reason, they have become mere religious and superstition. In ancient texts like the Vedas and Puranas, the fundamental science and purpose behind temple building is revelaed. They were built to be powerful spaces where people could imbibe the enshrined energies rather than just as places of prayer or worship. Most temples were created to address certain facets of life and were thus consecrated to accomplish specific objectives. Based on esoteric ideas the chakras, the energy centres within the human system were activated in specific nature in specific temples.

The position of the deity is proven to be in a position where there is a high field of earth's magnetism from the pole thrust. This is solid evidence that the past had advanced science. Copper's presence under the idol radiates energy, and the almost closed chamber of the garbhagriha resonates and reverberates for the visitor to absorb. The quantum mechanics of these reverberations are mathematical and purely calculative, and henceforth, the geometry associated with the built form to induce a certain frequency for the visitor to experience a certain feeling is absolute.

Selection of Site

The Sthapathi who is in charge of the planning goes to the designated area. By building a gnomon (column) in the center of the site that tapers toward the top, they are able to identify the cardinal points like given in figure 1.

The vastu-purusha mandala's corners are then indicated, along with its outer line. In order to make the construction site as close to the vastupurusa mandala's concept of a flat square world as possible, the entire terrain is then levelled.

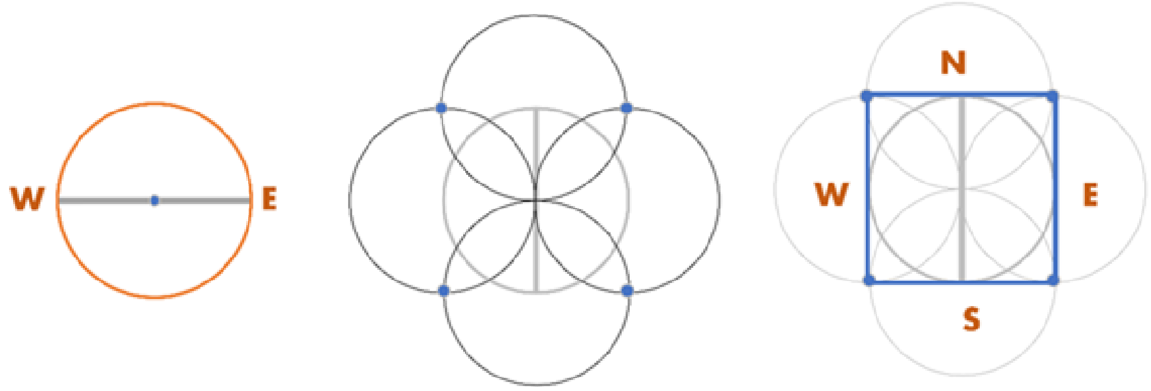

Figure 1 : Marking square on site

The Square and Rectangle Geometry

The use of square or rectangular shapes in Dravidian temple architecture is deeply rooted in the principles of temple construction. These shapes hold significant symbolic and cosmic significance and are integral to the overall design and layout of Dravidian temples for several reasons. This geometry is the foundational building blocks of mandalas, and they are used to create a grid that organizes the temple's layout and the placement of various elements. The base of the temple is aligned with the cardinal directions, particularly with the main entrance facing east. Square and rectangular shapes are considered stable, balanced, and harmonious. They represent order and structure. These shapes distribute the weight of the temple evenly, ensuring structural integrity. These shapes are visually pleasing and create a sense of order and proportion in temple architecture. They are relatively straightforward to construct, which was important in ancient times when temple builders relied on manual labour and simple tools. These shapes could be easily measured and laid out accurately.

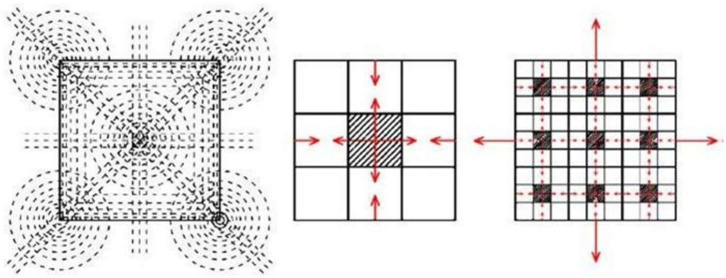

Figure 2 : The forces acting in square

The energy transfer and force bombardment in a square occur at distinctive pattern where ethe corners reverberate and echo back concentrating the center. This allows the temple to accumulate energies and cosmic forces and channel it through the inner sanctum.

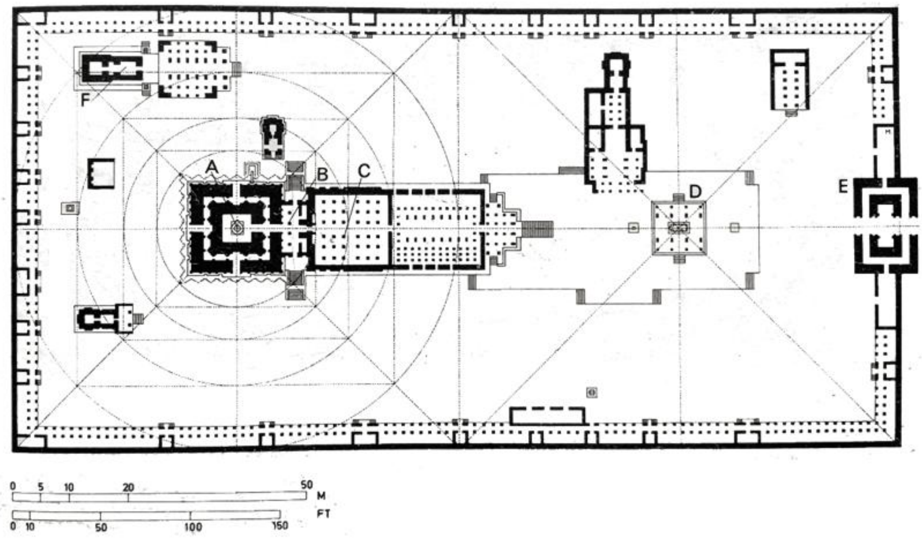

Figure 3 : Brihadeeshwara Temple plan
Reference: Croker, Alan. "Temple Architecture in South India." Fabrications 4, no. 1 (1993)

The temple follows Triyuta mandala which has 16 padas in each side. The overall temple complex follows a complex geometrical superimposition. Open space-built form is calculated through concentric circles taken through the square vertices. The golden ratio is followed in the overall layout where the ratio is functional at different levels and intensity.

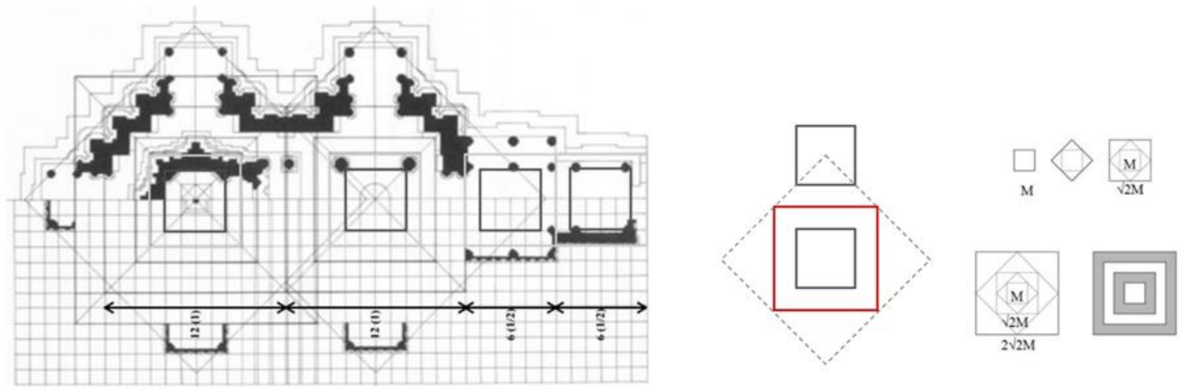

Figure 3 : Kandariya Mahadev Temple plan- 12 padas (left) and Addition of Mandapa to the Sanctum, Thickness of consecutive walls (right)
Reference: Mandapa: Its Proportion as a tool in Understanding Indian Temple Architecture, International Journal of Scientific & Engineering Research Volume 10, Issue 7, July-2019

The temple follows Desiya mandala having 12 padas square. This is also replicated in other parts of the temple when additions occurred. Thought the inner core geometry is replicated it is carefully articulated in such a way that the inner sanctum has the smallest volume.The disposition of mandapa is also done using geometrical layouts emerging from the mandala. The walls have been increasing at a rate of 1.414 times with largest wall being the walls of sanctum.

Units System

In antient era, the system of measurement was based on proportions and scale. A universal standard index was applicable as the relative proportions were given importance. Unit is specified when the relation to that is taken as account. This explains the uniformity in temple in different scales. Thus, when the proportional constant was a standard system of measurement, the basis of proportions being human, the human body was used to define the scale and thus a finger was used to calculate which was kept in refence to commonly used grain such as sesame seed and paddy grains. It emphasizes the idea that temples are not only places of worship but also spaces that connect the divine with the human experience. As a result, careful attention is given to creating an environment where devotees can engage in their religious practices comfortably and with a sense of reverence.

Table 1 Sthapati's Sirpachennool, Government of Tamilnadu

Table of space unit	
8 Anus	1 Car dusts
8 Car dusts	1 Immis
8 Immis	1 Ellu (sesame seed)
8 Ellu	1 Nel (unhusked paddy grain)
8 Nel	1 Viral (figure measure)
6 Viral	1 Taalam
12 Viral	1 Vitasi
24 Viral	Thatchu Muzham
27/8 Taalam	**1 Hastam**
8 Hastam	1 Dandam
8 Dandam	1 Rajju

Table 2 Convertion of angulas to modern unit system

Kisku	24 Angula (1 cubit/ Hasta)	72 cm
Prajapatya	25 Angula	75 cm
Dhanurmusti	26 Angula	78 cm
Dhanurgraha	27 Angula	81 cm
Prachya	28 Angula	84 cm
Vaideha	29 Angula	87 cm
Vaidulya	30 Angula	90 cm
Prakirna	31 Angula	93 m

The mathematical calculation of Vastushastra is based on Aayadi formula which is used to find the length, breadth, perimeter, area and the height of the building. The Aayadi formulae is the composition of equations. The remainder obtained plays an important role and considered as deciding factor of dimensions. the structure is proportionate and stable if the dimensions are in accordance with these formulae. The explanation of all its composition is listed out as follows:

- Aaya – It is the remainder obtained when length is multiplied by 8 and divided by 12.
- Raksha – It is the remainder obtained when length is multiplied by 8 and divided by 27.
- Vyaaya – It is the remainder obtained when breadth is multiplied by 9 and divided by 10.
- Yoni – It is the remainder obtained when breadth is multiplied by 3 and divided by 8.
- Vara – It is the remainder obtained when height is multiplied by 9 and divided by 7.

Tithi – It is the remainder obtained when height is multiplied by 9 and divided by 30.

As a result, a temple of these proportions must face northeast. However, this is unlucky because the remaining amount should be zero (east) or at least four (west). Consequently, one would have to start the computation over with different dimensions before figuring out which lunar day or planet this temple should be built under. An additional complex element is that the determined lunar day must ultimately align with the computed weekday, and this process continues until all equations are resolved with the intended outcome. It is very hard to meet all these requirements because the deciding factor is always the incalculable remainder of a division sum, not the six equations with their six unknown quantities. The perimeter of the structure having 2-18 cubits breadth is 11 cubits and 9-18 cubits is 39. Here 2-18 cubits is 66 angulas. On dividing it with quarter of cubits we obtain 11. i.e., quarter of cubits is 6, thus 66 divided by 6 is 11.

$yoni = \frac{P \times 3}{8} - R$	$= \frac{11 \times 3}{8} - R$	R is 1	$= \frac{39 \times 3}{8} - R$	R is 5
$vyaya = \frac{P \times 3}{14} - R$	$= \frac{11 \times 3}{14} - R$	R is 5	$= \frac{39 \times 3}{14} - R$	R is 5
$aya = \frac{P \times 8}{12} - R$	$= \frac{11 \times 8}{12} - R$	R is 4	$= \frac{39 \times 8}{12} - R$	R is 0
$rksa = \frac{P \times 8}{27} - R$	$= \frac{11 \times 8}{27} - R$	R is 7	$= \frac{39 \times 8}{27} - R$	R is 15
$tithi = \frac{P \times 8}{30} - R$	$= \frac{11 \times 8}{30} - R$	R is 28	$= \frac{39 \times 8}{30} - R$	R is 12
$vara = \frac{P \times 8}{7} - R$	$= \frac{11 \times 8}{7} - R$	R is 4	$= \frac{39 \times 8}{7} - R$	R is 4
$vayas = \frac{P \times 8}{27} - Q$	$= \frac{11 \times 8}{27} - Q$	R is 3	$= \frac{39 \times 8}{27} - Q$	R is 11
	11 cubits		39 cubits	

Hence for 11 cubits structure the reminders are specified. To have different reminders one must choose a different length and check with the corresponding resultant and henceforth arrive at a length.

Vimana Shape

The temple's design incorporates a pyramidal structure, with each successive layer of stones reducing in size as it ascends. This feature architecturally helps distribute the weight of the superstructure evenly and prevents the accumulation of stress at any specific point. The wide base and the tapering shape made it less susceptible to collapse, especially in areas prone to earthquakes. The vimana shape is aesthetically pleasing and impressive. It was meant to awe visitors and symbolize the power and grandeur of the god. Many scientific researches have been made to understand this shape and its significance over other structures. A study on Effect of pyramids on microorganisms By Itagi Ravi Kumar, N V C Swamy and H R Nagendra concludes through an experiment on different pyramid shapes and bacteria in it that specific shapes such as pyramid inhibits the growth of and different inclination provide different results

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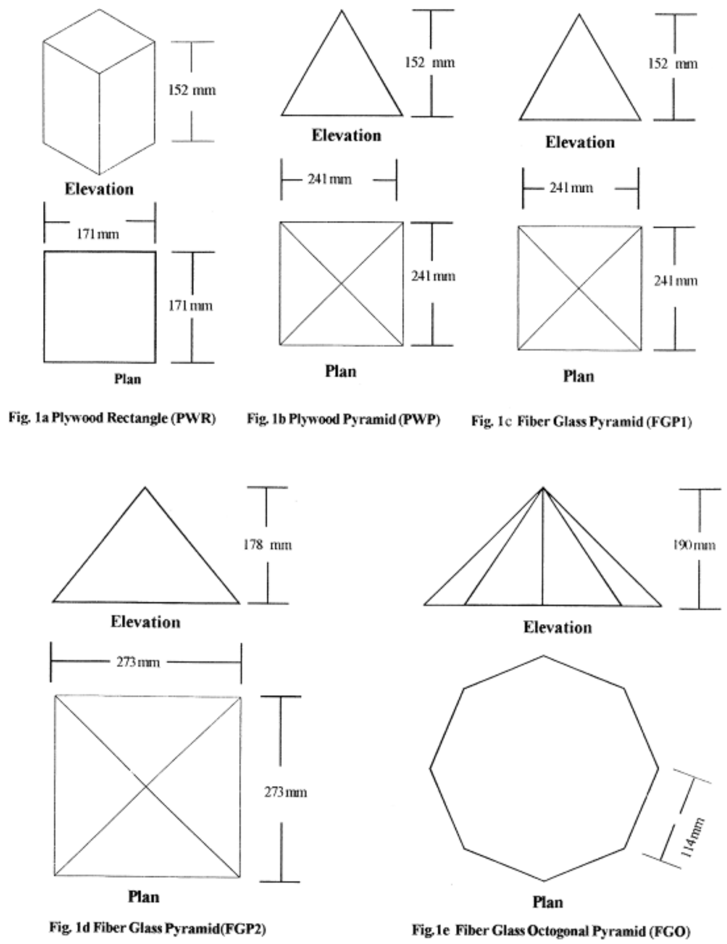

Figure 4 : Pyramid models from the study
Reference: Kumar, I. R., Swamy, N. V. C., & Nagendra, H. R. (2005).
Effect of pyramids on microorganisms.
ResearchGate.https://www.researchgate.net/publication/228495537_Effect_of_pyramids_on_micro organisms

The study shows that some samples do not undergo any deterioration at all. The only difference between them is that their bases are different, one of them being square and the other octagonal but has differnent results. Also, both of them are larger in volume than the other models used. This naturally leads to the question if there is any optimum size for which the pyramid is most effect

Energy Transfer

The aerodynamic shape of temple head and conical upper part of the structure attracts the positive charges from clouds. This Positive energy surrounds the whole internal surroundings of temples providing with a sense of positive mind, thinking, and health. This is done by aligning the vibrations of the human body in certain way to experience wellness or intended cause. The metal kalasa, or top of the vimana, attracts and intensifies energies and tapers to a finial. A study on pyramid of Giza named 'The Overall Science behind the Pyramid' is done by K.S.Vishwanath Vashisht, Assistant Professor, Department of Aerospace Engineering, Amity University, Manesar, Gurgaon, Haryana, India. where the energy flux inside is determined.

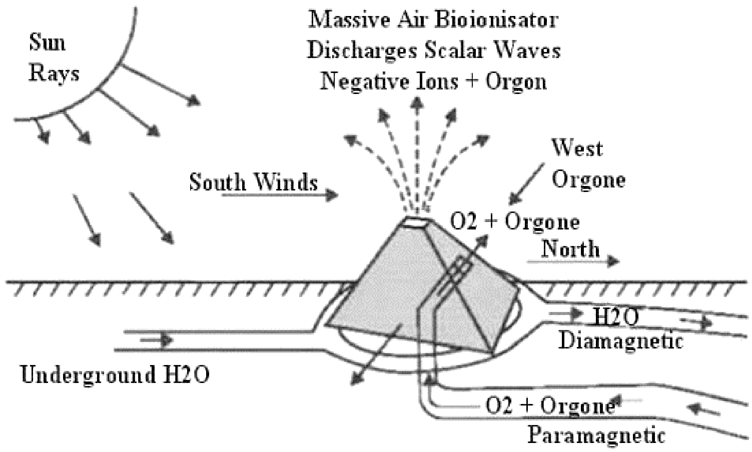

Figure 5 : Energy transfer in Pyramid

Reference: App, P. H. (2023, December 16). Pyramids: an ancient marvel of energy and architecture. Medium. https://medium.com/@ipemftherapy/pyramids-an-ancient-marvel-of-energy-and-architecture-e7837a45cfd7

According to the study, the pyramid must constantly vibrate in order to generate electricity andthe ideal locations for the pyramid are those where electromagnetic waves are more prevalent on Earth's surface. This produces the necessary vibrations for the crystals to always vibrate. Additionally, the diamagnetic granite pyramid floors are connected to graphite rods. Negative ions from the surrounding air travel to the upper layers of the pyramid, creating the electromagnetic field that forms at the base. This makes it easier for negative ions to conduct to the tip's outer regions. In order to increase the ionic content, a copper or gold cap stone is fitted at the tip, causing the ions to try and reach the surrounding area and ionosphere. As a result, the ozone layer grows and pollution decreases.

Thus, the inference from the study with reference to temple architecture concludes:

Negative Ions help to reproduce and repair body cells. They enter the body through the air and travel throughout the body through the blood. Conditions like depression can arise from an excess of positive ions in the air due to pollution. Negative ions are produced by pyramids. They also have a balancing effect on the electromagnetic field of the body. The metals in the kalasam significantly intensify this effect.

Anions purify water. Temples usually have stored stagnant water in a nearby temple tank. Which gets purified with the tower. The position of the tank is also favoured to complement the electromagnetic field.

Help store grains and food without spoiling for longer period.

Increase the growth rate of surrounding plants.

Help attain increased relaxation.

Promotes healing of cuts, bruises and burns, as well as reduces pain from toothaches and headaches.

Meditating inside a temple makes feel warmness, a sense of weightlessness, tranquillity, relaxation, enhanced focusing, positive approach can be observed because of the flow of electrons.

Modern temples

Many religious structures are built newly as ever. There is a huge question to the guiding principles to these temples. The proclamation to have used Vedic knowledge and guidelines is often seen vaguely but they do not reflect the core of these guiding principles. Though some have to be cautiously avoided when the era is changing and evolving there has been addition and omission of aspects that contradicts to the very basis of temple guidelines. Few case examples have been taken to illustrate.

Akshardham

The architectural style of the Akshardham Temple complex is said to be inspired by traditional Hindu temple architecture and used principles of Vaastu Shastra and Agama Shastra. The temple complex showcases the traditional Nagara architectural style. Remarkably, the temple complex was constructed without the use of metal or iron. The entire structure is held together using interlocking stones, a technique reminiscent of traditional temple construction. It is said that the Shilpa shastras, ancient and middle-aged Indian treatises on architectural science, were taken into consideration when designing the mandir, or inner sanctum.

Though the planning is said to be in accordance with sastra, the main Aayadi sastra that guides the sanctum proportions are not followed as the length of the sanctum can go up only 15-10 cubits which is around 35 feet while this is 45 feet wide which is exceeding the maximum allowed length according to Aayadi. The whole idea of energy transfer, resonance and consecration is not possible here.

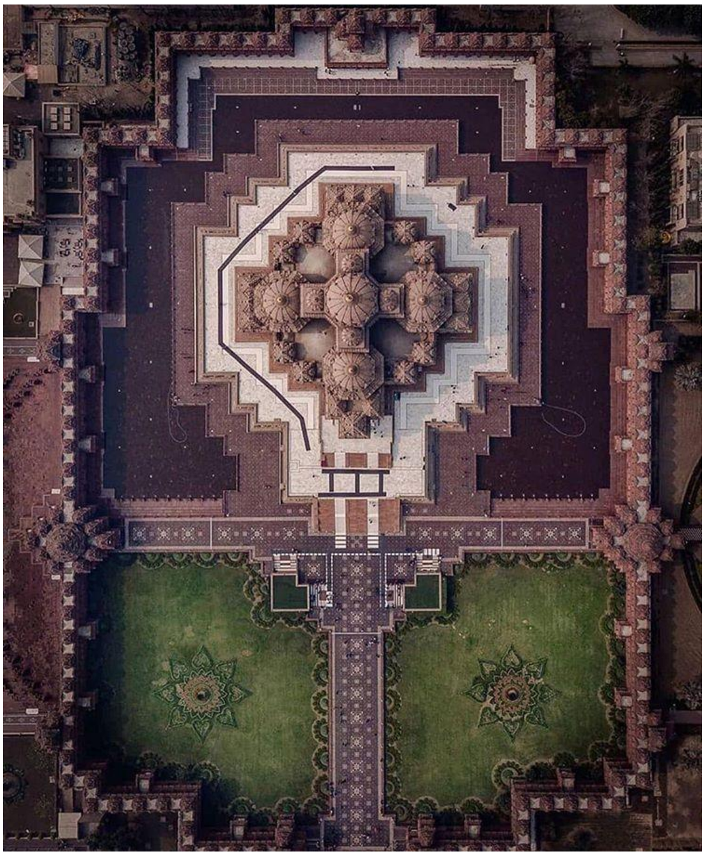

Figure 6 : Akshardham temple plan (top), garbhagriha (bottom)

Iskcon

The International Society for Krishna Consciousness (ISKCON) has constructed numerous temples around the world. It's important to note that each temple project have unique characteristics and considerations in architecture and planning.

These temples are contextual and adapt to local and contemporary design style. But the temple architecture according to Vedas is just the opposite where universality is projected through guiding principles and uniqueness is brought in the combinations of these principles.

Thought the basic form and design elements are considered, the logic being this usage is uninterpreted. The glass faced in Bengaluru temple just diminishes the material usage and contextual understanding. Similarly, huge openings in the tower which is unlike the guidelines of vimana etc. Most of these structures are made to cater large public and hence a big structure is raised. But the build space open form used in antient architecture is unseen here in most cases henceforth contradicting to most temple science and the aspects to which the guidelines where framed.

Figure 7 : Iskcon Temples- Mayapur (top left), Bangaluru (top right), Delhi (bottom left), Chennai (bottom right)

Antient temples with modern systems

Most of the bigger temples in South India are not the works of a single ruler. They have been added upon by successive generations of rulers. The method was to add a new layer of Prakaram outside the existing one, with even grander Gopurams without hindering the planning of the inner sanctum. Mandapams were added along with these, either as free-standing entities or as connecting passages from Gopuram to Gopuram and finally leading to the inner sanctum.

It was these Mandapas, which, due to their sheer size and depth allowed minimal and diffused light inside. Whether this was intentional or an accident can be contested. But what remains true is the ambience that is created inside, which contributes positively to the space formation.

The low level of light creates a mystique and meditative environment and aids in directing the devotees' minds solely towards the deity. This is worth experiencing and extremely difficult to visualize otherwise. Dark or low-light environments reduce the amount of visual stimulation that the eyes receive. When the eyes are exposed to bright light, they have to work harder to process visual information. While a darker environment can be less visually stimulating, allowing the eyes to rest and the eyelids to relax. Darkness is also important for regulating the body's circadian rhythms. Exposure to bright light, especially in the evening, can disrupt the production of melatonin, a hormone that helps regulate sleep. A dark environment can signal to the body that it's time to rest and promote relaxation. This overall relax makes our boy susceptible to absorbs energies without resistance. And thus, the flow of charges in accordance with other sensory activities, our body is rejuvenated. The air conditioner dismisses the energy transfer as chilled air is pushed mechanically which contradicts with the harmony of energy flow. To accommodate many people this was introduced, But the whole idea behind temple is being forgotten.

Figure 8 : Airavateeshwarar temple- Dark mandapam

Figure 9 : Chennakeshava temple- Additional railing

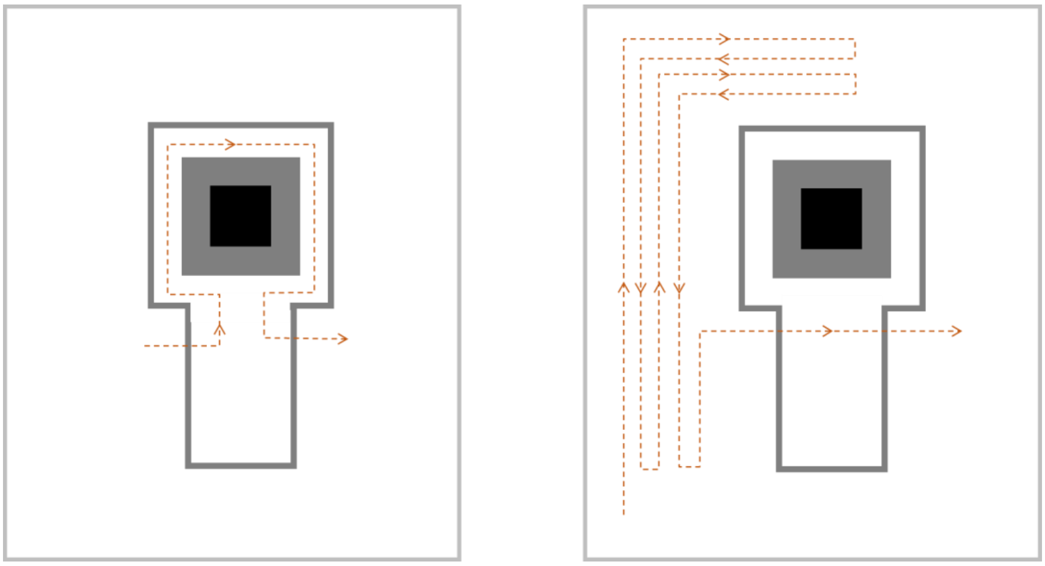

Figure 10 : Circumambulation movement

The mixture of modern materials is another major problem with natural vibrations of the temple. Recent mindless additions to beautify the temple result in changing the effect of energies on human bodies as materials play a major role in energy reverberation. The polishes tiles in inner sanctum does not help reverberate sounds and energy.

The direction of people in large temples with increased human influx, directs people with a queue where the direction in which the circumambulation should happen isn't accommodated fully. This will hinder the effects on body. In many temples most spaces are closed due to protective governance. But these are integral to the functioning of temples. As few structures like temple tanks are meant to be used as rituals before entering the sanctum to orient our body for certain energy reflexes. But a hindrance collapses it all.

CONCLUSION

The rapid urbanization and growth due to the modern technological bloom resulted in unsustainable, directionless, and temporal actions and solutions to it. Ancient science came into existence through a long evolutionary journey. Temples are manifestations of science centres that achieve their intended goals extensively and are more centric on the everyday lives of people. But eventually, these sciences faded away, leaving a strong layer of religion, superstitions, and myths. The complex layer of temples is broken down to guidelines in Vedic literature for easy understanding and errorless non subjective approach. These have become complex as the world evolved to forget the language that these texts used. Thus, deciphering these and drawing guidelines that is in par with modern day discussions and technologies is invariant for application of these guiding principles.

Many temples have become a mere religious space where many changes are taking shape to accommodate the large influx and modern living standards. The lives of people have changed so drastically that the changes are necessary but the decisions have to be carefully made through learning the core of the science behind the built form of temples and their importance in human activities. Any changes to adapt to modernity should be carefully examined and approached. The science of these structures is extensive and they can be harnessed in various other fields of architecture and built environments. Though various understanding we can conclude that temple structures were used as passive science lab and centres of energies. It could be a crucial step to master these passive way of energy centres for the current trends of sustainability.

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Community Engagement in the Development and Operation of Smart City Mission: A Comparative Study of Two Cities

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Abstract— India's 2015 Smart City Mission aimed to promote cities with core infrastructure, sustainability, and improved quality of life through smart solutions, driving economic growth and inclusivity in 100 selected cities via comprehensive development across social, economic, physical, and institutional pillars. Effective Community engagement: a core principle of the Smart Cities Mission, is vital for the success of the mission, as it considers diverse local needs and foster inclusivity. However, an inconsistency in community engagement was seen across the mission's cities. The research aims to investigate the extent and nature of community engagement in the planning, implementation, and operation of smart city mission, focusing on a comparative study of two cities – Pune and Indore. Mixed research methods are undertaken to synthesis, compare and analyse the data collected from formal and informal discussions with various stakeholders. The paper will conclude by identifying practices of community engagement and challenges of development and implementation faced in the two selected cities. The paper will contribute to the growing body of knowledge on smart city development and provide practical insights for stakeholders involved in the process of governance and planning.

Keywords: Community engagement; Smart City Mission; inclusivity; Pune; Indore

INTRODUCTION

Cities, a definitive result of urbanization, are centres and driving forces of economy, technology, and culture. The economic development in cities is accompanied by provision of efficient infrastructure, health facilities, transportation, better living standards services. It also attracts skilled talents and labours allowing the cities to develop as technological centres and witness the rural – urban migration which develops a mixed-cultural environment (UN-HABITATS, 2012). The year 2007 witnessed a significant shift first time in history, where the world's urban population outgrew the rural population as mentioned by UN World Urbanization Prospect (2019). The urban population has continued to expand, with 2030 projected to witness 5 billion people living in cities, with Africa and Asia being the forefront with population doubling by 2030 and the developing countries comprising 81 percent of urban dwellers (PRB, 2007).

Though rapid urbanization brings great advantages in cities, they also create new challenges like the increased use of natural, unsustainable resources and the decreasing of living standards due to the increasing large population and decreasing land area (Haughton, 1997). This has led to several suggestions being proposed, one of them being "the Smart City" concept. Introduced in the 1990s, Smart cities has significantly evolved from cities to integrate technology and digital innovations in all forms to improve globalization and urbanization. Characterized by a plurality of definitions by various researchers, Smart cities are cities which uses Information and Communication Technology (ICT) to improve interconnection, efficiency that result in intelligent developments with wise management and inclusive development for all urban-dwellers. Countries across the globe have launched their versions of "smart city projects, plans and proposals" to resolve the urbanization challenges they face (Yin, et.al., 2015). One such program is the Government of India's, "National Smart Cities Mission" (2015) under the Ministry of Housing and Urban Affairs, an urban retrofitting and renewal program proposing to develop 100 resilient, sustainable, and community-friendly cities. This was proposed to increase economic growth by using technology and resources in a sustainable way while improving the infrastructure, disaster management, city management and overall living conditions of urban dwellers by reducing the economic barrier. The mission incorporates efficient land use practices, sustainability, expansion of housing and infrastructure development, reduced dependency of vehicles by improving walking facilities and public utilities, digitalized transport systems, economic growth (through industries, tourism, and education) (Kumar et.al., 2018). The fundamental principles of the mission are –

- Community Engagement in planning and implementation;
- Generation of greater outcomes from lesser resources;
- Corporative and Competitive federalism with flexibility to project implementation;
- Integration, Innovation and Sustainability;
- Technology is carefully selected and implemented in the city design and management;
- Sectorial and financial convergence (Smart City Mission, 2020).

Since the mission places emphasis on community engagement as a core principle, the paper explores how vital is the role of community engagement in the effective development and management of smart cities. A comparative analysis focusing on two cities under the mission - Indore and Pune is undertaken to illustrate how active community engagement plays a crucial role in the success of a smart city.

LITERATURE REVIEW

While the research on smart cities dates back to the 1990s, the last decade witnessed a surge in interest on smart cities. This interest in smart city research is primarily due to it being viewed as a solution for governments to combat the various urban concerns like rapid urbanization, environmental pollution, demographic shifts, and digital disruptions (Tompson, 2017). The majority of smart city research are categorized in four areas – technology and infrastructure, community engagement, the government policies and economy.

Trencher indicates that "smart city" research has seen a resurgence which focuses more on fostering better collaboration and community involvement, unlike the first emergence, where it was more technological and economically driven (2019). This transformation in interest to community participation was a response to the questions raised in the previously which criticized the focus and approach of smart city initiatives. One research in 2008 critiqued the assumption and labelling of smart cities, therefore advocating for a inclusive and progressive approach (Hollands, 2008). This was supported by other findings which highlighted that, favouring technologies and corporations while failing to understand citizens would result in unsuccessful smart city projects, as seen in many projects around the world (Carrasco-Sáez et al., 2017; McFarlane & Söderström, 2017; Trencher & Karvonen, 2017).

Though community engagement has now been put forth as an important principle in recent smart city projects, the definition of community engagement is vague. An example of this is the "Smart City Challenge" undertaken by the Canadian government, where applicant consultations and partnership were different and extremely flexible which raised question of the effectiveness of such engagement. The SCC's encouragement for community participation in urban planning highlighted the contradiction of opportunities for direct community involvement between bureaucratical top-down and bottom-down planning (Goodman et.al., 2020). Another study found literature research on that citizen participation in Eurocities and smart cities had a significant growth since 2015 concluding that it is a highly relevant topic in the theory of public management and democracy with smart city initiatives to give more focus on how cities became smart without discussing sector-specific initiatives. The actual implementation of community participation in Eurocities focuses more on sector-based initiatives to emphasis and work on social issues. Eurocities have seen a change in power structure with the introduction of open participation in policy making arena within the smart cities, leading to improved innovation, diversity, and creativity within the smart cities. The literature review and the empirical experiences of community participation in eurocities shows that which literature promoted solutions like ICTs like mobile applications etc, empirical experiences mainly based their community participation on offline and face-to face events like meeting, seminars etc with the local government playing the lead role, though there are not enough research to conclude which approach is a better one. Further, the study also suggests creative cities have conducted more participatory initiatives that emphasizes technological participative solutions like social media, living labs than non-creative cities, which makes it easier for citizens to participate in the decision making for innovative cities resulting in citizen-centric solution, better quality of life and higher economic growth (Cortes-Cediel, 2019). But there has been a significant gap in how the participatory events are conducted, what are the impacts of these events and how the feedback or opinion is considered in policy making. But it has been noted that the current smart city community participation lacks the design to be relevant to citizens within their communities and is mostly generic disregarding the community's technology relevance, age, and access. This results in not an inclusive community participation. Kashem and Gallo found out that the new digitalized approach of connecting with citizens are failing to fulfil the limitations of the traditional approach of meetings, especially in the minority and low-income community (2023). This can be seen by how the Stoop Survey technique in Albany was successful, where the board members physically interacted in neighbourhoods with low participation at community forums and was met with support from the citizens (City of Albany, 2022).

In conclusion, community engagement plays an important role in the success of smart cities as it propagates inclusivity, social cohesion, and sustainable development (Trivedi, 2017). Smart cities initiatives like effective implementation of smart city technologies, need to align with the local needs which is achieved through empowering the citizens. Empowerment of citizens is only possible through active community involvement in decision and policy-making as it harnessed local knowledge while addressing social inequalities. Community participation enhances overall urban well-being which smart cities aim to achieve. But the government and planners should consider the modes of participation and develop initiatives based on preferred engagement approaches by the citizens as these can vary due to different ages, ethnicity, gender and prepare participation plans accordingly, rather than following a generic public engagement plan (Kashem and Gallo, 2023). Civic participation should be given practical importance and must be flexible

METHOD

The research aims to understand the intricate dynamics of community engagement in the development and operation of the smart city mission in India, with particular focus on a comparative analysis of the cities Indore and Pune, both prominent cities in their respective states, with Indore being ranked as the top smart city (2023), while Pune has faced few urban struggles in its quest to become a smart city. The mission has seen integration of technology and urban governance in innovative ways and understanding the role of community engagement is pivotal for effective implementation of these innovations. A mixed methods approach is adopted for this research which incorporates both qualitative and quantitative data sources to comprehensively understand and explore the nuanced approaches of community involvement in these two cities (Axinn and Pearce, 2006).

Data collection is undertaken by various online methods and informal interviews. A substantial component of the data is sourced from online news articles and online forums, which offer real time, current and dynamic perspective on community reactions and perceptions. The keywords – "Community engagement, smart city Pune, Smart city Indore" were primarily used as a systematic search strategy to gather articles from reputable journals. The articles provided insights into the community's awareness, concerns and response to the various smart city initiatives undertaken by the local municipal corporations, serving as a rich source of qualitative data. To capture the subjective and personal experience of community members, formal and informal interviews with different stakeholders in both Indore and Pune were conducted. The discussions with the community provided qualitative data that enriched the study by providing a deeper understanding of the live experiences of the residents and their interactions and opinions of the evolving urban landscape. It uncovers individual perceptions, expectations and critiques related to the smart city initiatives and acts as the community engagement needed for this research. Due to the limited nature of interviews and news article coverage, the study does rely on official government sites and documents to understand the formal policies and initiatives undertaken by local municipalities for the smart city mission in Pune and Indore. Comprehensive content analysis is conducted to extract information on government-led community engagement programs and urban planning strategies. This quantitative data is a foundation to access the formal structural plan of the government for community engagement, offering insights to the governing body's role in the status of community engagement in their respective localities. The theoretical knowledge of the importance of community engagement in smart city development and operation is contributed by thoroughly reviewing the existing academic literature research that enabled to ensure our research is grounded in established frameworks by giving a broader context of smart cities (Sutton and Austin, 2015).

The data collected through these methods will be analysed to identify the similar and different approaches undertaken by both the cities in terms of community participation. The triangulation of the data will offer a comparison and comprehensive understanding of the role of community engagement in the Development and Operation of Smart cities Indore and Pune.

RESULTS AND DISCUSSIONS

Indore and Pune, two cities under the smart city mission are dynamic cities, cosmopolitan cities that have preserved their cultural and historical essence. With a population of about 8 million and 3 million in Pune and Indore respectively, both can be considered metropolitan cities, though Pune is far larger as compared to Indore.

Community participation under Smart City Mission, Pune

Pune is an urban centre which has a reputation of being cultural, educational and is a developing business and IT district. The government is faced with constant challenges of preserving this diverse city and creating a balance between the past and present. It was one of the cities suggested for the Smart City mission from the state and has seen quite an effort made to develop itself as a smart city. The municipal corporation started of strong with spreading awareness of the mission by distributing citizen feedback forms door to door, which were collected in drop-boxes, taking out a rally organized by 15000 school children from different schools, online presence like Facebook page, newsletters, smart city idea competition and ward level citizenship engagement meetings. The Pune municipal corporation led the largest citizen engagement initiatives in India at the formulation phases of the smart city mission in 2015 where citizens participation was appreciated. It claimed to have engaged over 60 percent of the citizens in the initiatives. The Pune citizen engagement model utilized a 9-phase approach in 2015 which were envisioning, diagnosing, co-creating, refining, sharing, selecting of area, competition and profiling, Resident engagement and finally sharing and acceptance. The Aundh-Baner area was selected by citizen participation as the first local area for area-based development in the smart city initiative (Bagchi, 2024). The municipal corporation put in a lot of effort in increasing citizen participation during the first year of the mission with a proper plan which included partner eco-system, different modes of citizen engagement, defining the procedure for the citizen engagement and creation of "war room" which essentially tracked and monitored the entire effort (Development Monitoring and Evaluation Office, 2021). The modes of engagement used were – face to face meetings (door-to door visits by PMC officials, camps in educational and business institutions, distribution of forms and smart phones to the masses), digital and online presence (Pune smart city web portal, gamification for participation, Public computer terminals at *e-seva kendras* as well computer labs in schools opened to access the feedback portal, social media presence and smart phones application), Competitions(essays, area development, digital hackathon, smart family and smart citizen initiatives) and finally publicity and advertising like hoardings and banners, radios, television and gallery walk setup in war room all too build the citizens awareness of the smart city initiative (Pune Municipal Corporation, 2015).

There have been some successful citizen-input led projects in Pune under the mission like the street lighting project, which saw halogen streetlights being replaced by energy saving LEDs which could further be controlled remotely, the dockless, GPS bike sharing which could be mobile app operated and included about 3000 cycles in more than 150 locations and input on projects to convert vacant areas into smart service providing areas done via placemaking (Bagchi, 2024). The feedback results for a trail mock-up of redesigning of 100 km planned streets were that there was a need for open spaces, traffic reduction and better parking facilities, which was taken into consideration and the street planning committee proposed two-way traffic, universal accessibility, seating areas along the street, bollards to prevent vehicles on footpaths and wider footpaths (Agrawal, 2018). A river rejuvenation development project as well as a Bus rapid transit system project, currently in progress of execution stage, were also planned with input from the citizens. The lighthouse project, one of the successful projects, has brought in the poor youth population to learn skills to survive. This initiative considers the citizen participation to be successful and has been seen as a unique model.

But over the years there has been gap between the citizens feedback and participation to the development and operation of the smart city Pune. Pune was ranked 2nd in the smart city mission in 2015 but the lack of further citizen engagement and municipal transparency over the years has led to the rank dropping significantly. Research conducted about citizen perception about the mission in Aundh, Pune brought forth a ground reality of the mission. The study revealed that while most respondents knew about the mission and Pune being selected for it, just 74 percent knew of the initiatives undertaken to develop Pune as a smart city, with majority being unsatisfied with the initiatives undertaken and wanted more appropriate measures to be considered (Deshpande and Gupta, 2019). The residents think there are important promises which have not been fulfilled over the years. The residents claim that the only promised thing which was fulfilled was to develop footpaths that make the city walkable. They mention that the mission and PMC have failed on several initiatives, especially the monthly meeting to encourage citizen engagement. Citizen engagement was further decreased by not giving any updates on development, ignoring or uninviting citizens when they questioned, ignoring, or not considering suggestions from the forums which led the municipal corporation to develop initiative which were not of foremost important amongst the citizens. For example, in Aundh-Baner area, citizen's feedback regarding congested roads and land acquirement was ignored. The three gardens which were promised to be built have also not seen the light of day. Further, many projects do not have public support because of the lack of awareness which is due to poor communication from the officials. The officials also claim some projects are stuck due to lack of coordination from the various stakeholders (Bari, 2019). Furthermore, the footpaths have been encroached due to lack of governance (Khairnar, 2021). There is a gap in the citizen's feedback and voice are not being considered in the future developments of the smart mission, which would lead to the failure of the city being a citizen- centric smart city. There is also a lack of continuous operational support by the municipal corporation and a lack of community engagement in the operation of the initiatives which has resulted in several of them failing.

Community participation under Smart City Mission, Indore

Indore, the commercial capital city of Madhya Pradesh was the first city selected from the state for the Smart City Mission. The Smart city Mission in Indore is a success especially in terms of timely execution and delivery of the project and citizen engagement. Recently, Indore bagged the best Smart City award 2023.

Indore has a rich cultural history and heritage significance, due to its central location in the country, and has historically been a prominent pilgrimage and trade route site. Recently it has developed significantly in terms of industry, finance, education, and entrepreneurship. Since prior to independence, the city is familiar with community participation in planning policymaking, with residents having an input in the princely-run city planning. In 1918, to combat the plague that had ridden the city, participatory planning by the residents under the guidance of Sir Patrick Geddes was undertaken, which was successful. In modern times, Indore has a reputation of engaging in participatory urban planning which has continued since the past. Citizen engagement was a major part of the enhancement of city services and infrastructure program in the 1990s and 2000s which received support from UK Overseas Development Assistance (Basu and Karla, 2022).

The Indore Municipal Corporation led an extensive community engagement program that was carried out in three phases. It undertook various ways to spread awareness of this mission which included competitions with prizes, "Run/Walk for smart Indore" event, distribution of flyers and smart City Souvenirs at large gathering like garba and cricket matches, kiosks, and mobile vans. The second step was to encourage the public to participate in the mission to identify the problems and get suggestions on how to improve the city. Predominant engagement programs were conducted through online platforms like social media and e-platforms, which encouraged the youth population, which are the majority of the population. Face to face, interpersonal methods like focus groups and surveys were used to connect with the rest of the population like professionals to slum-dwellers (NIUA, 2016). The result of this community participation was the citizens selecting the areas for improvement in the city which were transportation, heritage, health, waste management, IT, and infrastructure (Basu and Karla, 2022). Data collected also showed that citizens would prefer upgrading existing areas, i.e., retrofitting areas, and developing the business district area in Indore. After the areas around Indore were selected, the government further conducted community engagement door-to-door consultation to understand the situation in the selected areas further. Further, the city also accepted feedback and comments regarding new draft proposal for improving the areas through online platforms (Dwivedi et.al., 2020).

Taking the citizens feedback into consideration, many projects in Indore have received significant community participation. The high level of community engagement from the citizens of Indore can also be seen in the Smart City mission, where one of the goals, to make the city clean, got immense active support and participation from the citizens and the municipal corporation (Basu and Karla, 2022), leading to Indore being crowned the cleanest city in India six times in a row. The city officials put in a lot of effort to educate the public about importance of cleanliness and waste segregation through awareness campaigns, which led to active citizen involvement in the cleanliness movement in Indore. Another initiative was the Kahn Riverfront Development, which led to the creation of parks and green leisure spaces, while improving water and sewage management. Other implementation in regards are smart poles, Sensor based underground bins, public bicycle sharing, reviving of heritage sites like retrofitting the Harirao Holka Chhatri, Rajwada area and improving roads by making them bigger to decrease traffic especially near the Rajwada Conservation area (Smart City Mission, 2023). To improve mobility according to citizens' wishes, the roads are being created to accommodate cycling and walking. The Saraswati and Kahn Lifeline project saw immense public participation that also raised awareness on safe sewerage disposal leading to improved water quality in the rivers and having a healthier aquatic ecosystem. It is also India's first Water Plus city, as it has improved water access, public toilets, and wastewater management. The Integrated Command Control Centre, a central system helps combine data from a range of sectors and services, helping in easier management of the city. ICCC also has integrated citizen reporting systems like the Indore 311 app and CM Helpline which helps citizens to raise complaints regarding anything in the city (Bakhtawar et.al., 2022; Smart City Mission, 2023).

Indore has maintained carrying out community engagement initiatives like group consultations and surveys till today, that helps in identifying the problems faced by the citizens as well as to get feedback and ideas to improve the city (Basu and Karla, 2022). While it has been noted that most of the feedbacks are from youths and more influential people, with citizens complaining that the citizen participation meeting, some of which are held in expensive hotels are not easily accessible to the most of Indore's population, there is a higher level of community participation in the city, with citizens having a vested interest in progress of the city (Dwivedi et.al., 2020). Moreover, even with ICCC there is a lack of data sharing across all sectors which is a persistent issue (Bakhtawar et.al., 2022), the status of developments around the city are regularly updated on online platforms, which ensures the citizens are aware of the development progress and making the process a bit more transparent and creating awareness. The success of the mission and its initiatives in Indore can be contributed to the co-ordination between people, local representatives, and government officials from the development to the operational stage. The celebration within the citizens on winning the 2022 smart city contest shows the awareness of the program and the effort put by everyone to encourage participation in every step of the mission initiatives (Asia News International, 2023).

Comparative analysis and key findings

While both cities have incorporated various degrees of community engagement, it can be seen the city with higher community engagement, i.e., Indore is more successful in the mission. Indore's consistent execution of projects based on citizen feedback led to tangible improvements in successful projects like Cleanliness, safety, and heritage, contrasting with Pune's declining rank due to execution gaps. Indore took on a more proactive approach in ensuring transparency while communicating about project updates to the citizens, highlighting the importance of clear communication in maintaining citizen satisfaction. Indore, unlike Pune, has shown better coordination between citizens, officials and local representatives which has contributed to successful outcomes, emphasizing the importance of active stakeholder involvement in developing and operating a smart city. Though both the cities have vast areas to improve their community engagement techniques. Three areas which they should focus are -

- Engaging all demographic and age groups in citizen participation missions
- Giving more power of decision making in development policies
- Citizens should be engaged and inculcated into the operation of the initiatives.

Table 1: Comparison between two cities

Cities	Citizen Engagement Initiative	Modes of Citizen engagement	Project Implementation	Transparency and Communication	Overall outcome
Pune	Biggest initiative in India. Done in 9 phases	Face to face meetings, digital platforms, competitions and awareness programs in schools and institutions	Most of the projects did not consider citizen inputs especially in recent years. Operation of the projects also did not engage citizens	Decline in citizen engagement and participation due to the lack of continuous operational support, poor communication from officials, ignoring citizen feedback and no updates on development projects.	While Pune initially demonstrated strong citizen engagement, the gap between citizen feedback and project execution, coupled with communication issues, led to a decline in the city's smart city ranking and dissatisfaction among residents.
Indore	Quite efficient, done in 3 phases to reach various demographic groups	Competitions, events, online platforms, and face to face interactions.	Some form of citizen engagement and participation was seen in development and execution of many initiatives like the clean Indore initiative.	Indore maintained transparency through regular updates on online platforms, ensuring awareness of citizens in development progress. There were some complaints about accessibility to citizen participation meetings but overall, a higher level of community participation was seen.	Indore's Smart City Mission stands out for its successful project implementation, driven by extensive community participation and effective coordination between stakeholders.

Table 2: Smart City Ranking and Community Participation level

City	Population	Smart city accolades	Majority of age group participation	Community Participation at the start	Present level of Community participation
Pune	7.3 million	Dropped from 2nd position (2016) to 13th position. 2nd in citizen engagement in 2016 Good infrastructure and IT development	Youth	Highest	Low
Indore	3.4 million	2022 winner of smart city 6 times in a row winner for cleanliest city in India 1st in built environment, culture sanitation and economy (2023)	Youth	High	High

Pune has underscored the significance of continuous citizen engagement and aligning project execution with citizen's priorities, leading it to drop rank amongst the smart cities. In contrast, Indore has tried to maintain its citizen participation till this day, which has led to it transforming into a successful smart city, with citizens not having any misgiving of the prioritization of development in the city.

CONCLUSION

Indore and Pune both aspired to address the urban challenges prevalently faced by the citizens in the cities, by introducing innovative challenges, but their approaches to community involvement have varied significantly. As seen from Tables (1 and 2) and data collected, community engagement is essential for the success of the Smart City Mission in India. A high level of citizen participation and engagement can help change the urban landscape as the policies and developments take citizens into consideration. It must be noted that Pune, with its higher population, which is increasing at a faster rate than Indore is much harder to manage than Indore. Indore, having a rich history in participatory urban planning, demonstrated a more proactive approach in engaging citizens at every step of the smart city mission as compared to Pune, which faced challenges in sustaining their successful community engagement methods over time. The disconnect between citizens and the governing body grew wider in Pune leading to dissatisfaction among the citizens with the developments taking place in the city. But the alienation of the community in the future projects and no input in the operation of the projects decreased the impact and effectiveness of the smart city mission in Pune reflected in Pune's diminishing rank among smart cities.

While both Pune and Indore had a good first response to the smart city mission with extensive community participation to identify the problems, it has certainly decreased over time. However, Indore still has a higher level of community participation with the municipal corporation being more receptive to feedback. "Spreading Awareness" is one of the major things which has been imbibed by the Indore Municipal corporation, so the citizens are still invested in the Smart City Mission, unlike that in Pune. Despite these differences both the cities need to improve their community engagement techniques by including most of the citizen demographics, being transparent and by creating means to make smart citizens. The comparative analysis underscores the importance of continuous and inclusive community engagement in the success of smart city initiatives. Indore's case highlights the transformative impact of active citizen participation and collaborative governance in driving smart city development. Cities aspiring to become smarter must consider prioritizing citizen involvement across all stages of planning, execution, and operation, along with technological advancement. Citizen engagement should be socially inclusive and responsive to the needs and aspirations of their residents.

In conclusion, the research highlights that for efficient development, execution and functioning of smart cities, community engagement is extremely essential. Therefore, a citizen-centric approach to designing smart cities is necessary to unlock the full potential of smart cities which results in creation of a more resilient urban environment.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Factors Affecting the Property Values in an Urban Area

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Abstract— Property value is a dynamic term that depends upon various parameters. Limited controlling parameters of property value are present in individual literature, which emphasizes the need for a comprehensive list of parameters and their weighted importance & relative ranking. This paper focuses on identifying factors affecting property values in urban areas and formulating a framework on the relative weights of these parameters. A systematic literature review is done by short-listing the papers using the PRISMA model. The literature search is done using "factors impacting property values," "valuation factors of real estate and infrastructure," and "parameters of property values" on Google Scholar, Research Gate, and Scopus databases. The literature search is carried out for general and residential, properties. One hundred twenty factors are identified through an exhaustive literature survey. These 120 parameters are then reduced to 66 which are further clubbed into ten main factors. The weight and relative ranking are assigned to the identified factors by the Delphi technique with a 5-point Likert scale. The experts for Delphi are drawn from academia and industry working in the real estate field, including real estate consultants, developers, financiers, and policymakers. The study shows that location and accessibility are the major factors that significantly impact property values. This paper addresses this gap in the literature, gives some executive implications, and finds out this area for more comprehensive research on different real estate market sectors.

Keywords: Property values; Real Estate; Parameters; Accessibility

INTRODUCTION

Property value is significant for the stakeholders for their varied purposes. It is one of the critical components of the domestic and national economy. Property values are determined by inter-relationships of various factors (Oloke et al., 2013). These factors vary with the variation in geography and socio-economic property value moving up and down, which depends on several parameters. Therefore, it is essential to recognize the critical factors and their significance on the property values profile of the region/city (Ge & Dus 2007). So, it becomes imperative to determine those various factors for valuing properties. Property values increase with the availability and improvement of physical and social infrastructure, and they grow less rapidly in the areas that need those facilities. It has been proved that the cities with adequate transportation and economic growth have continuously hiked in land and property values. Property value is more appropriate for any built structure in terms of real estate. Real estate value is always associated with utility, which means no utility, no value. As per the fundamental theory of housing economics, it is well-established that in a market, product value inters a relationship of demand and supply.

LITERATURE REVIEW

Property value is an essential market aspect that is determined by various factors. So, understanding those factors and their relationship is a significant part of valuing properties (Ge & Du, 2007). (Kong Raymond Tse Peter ED Love et al., 2000) identified and grouped those factors into four categories: structural, physical, neighborhood, and environment for residential property values in Hong Kong by hedonic equation. As per the study done by various researchers (Golub et al., 2012) (Sayce, Cooper, Smith, & Venmore-Rowland, 2006; P. et al., 1997), the sub-factors were clubbed under location, physical, legal, and economic factors. According to (Values et al., 2001) (Wyatt, 2013), the factors that affect property values are location, physical attributes, and legal and environmental factors—accessibility and proximity to infrastructures clubbed under the location parameters. The biological factors included the structure parameters of the property, which included condition, size/area, and age of the building. Legal factors often included terms and conditions applicable to the properties. (Malhotra and Rastogi 2020) Studied the impact of MRTS on housing pricing using Hedonic regression and divided the factors into Spatial and Temporal. Spatial attributes took into account the characteristics of space dimensions. Temporal attributes considered the dimension of time, and the study was based on the pre & post-construction of the metro corridor. (Karthigeyan and Chand`er 2020) They analyzed the impact of the Chennai Metro station on the development in the influence zone (within walking distance of 10-12 minutes) by examining the effect of the metro station's accessibility and other factors, including the availability of MRTS. They concluded that the development depends on metro stations and other parameters such as population density, distance to the Central Business District (CBD), etc. He identifies eight parameters from previous literature studies. (Ayse Yavuz Ozalp and Halil Akinci, 2017) they studied the impact of structural and environmental parameters on the real estate value in Artivin City using the Analytic Hierarchy Process (AHP and found that the structural value was five times more than the environmental value. 80 parameters were selected from various literature studies, and after discussion with experts in real estate, a total of 25 parameters were considered for the study. (Malhotra et al., 2016) the impact of MRTS & BRTS on property values was compared and found that the property values were higher in controlled areas than in the catchment areas by using the multilevel model to measure the increase in housing prices, considering neighborhood characteristics and accessibility parameters. The study (Anantsuksomsri & Tontisirin, 2015) determined how mass transit directly influences the residential property values in the Bangkok Metropolitan Region, Thailand, using GIS (Geographic Information Systems) and spatial econometrics. The study concluded that proximity to MRTS positively impacts residential property values. (Swamidurai, 2014) concluded that urban growth and land values are directly proportional, as the land value increases with an increase in urban sprawl, and the study emphasized the proper future planning of cities and urban sprawl. Still, the economy, urban sprawl, location, land use type, availability of infrastructure, and land scarcity play a crucial role in Chennai city. The paper highlighted the importance of land value analysis for city development.

(Zhang et al., 2014) the study emphasized the significant influence of the Mass transit system on the property and compared transit technologies like BRTS, LRTS, and MARTS in Beijing by Hedonic price mode. The study concluded that the property values are higher in the case of MRTS, and values go down as we move from the transit station. (O & O, 2013) gave preferences to the infrastructure facilities like water, electricity, transportation, and medical facilities, which impact the property values in Unity Estate in Lagos Metropolis. With the help of a survey, The study ranks the physical infrastructure as the most critical facility impacting property values. (Golub et al., 2012) examined the BRTS on the land market in Seoul, Korea, through the multilevel model, as Seoul was the World's densest and most congested city. They concluded that the improvement in the BRT system compelled property owners to change single-family houses into higher-density apartments. (Pagliara & Papa, 2011) examined residential, office, and retail property values around the new stations from 2001-2008 and found that the property values were higher near the CBD area and lower in the catchment areas. (Gu, 2011) the hedonic price method examined the impact on the property values of Beijing's residential, commercial, and retail properties. The finding found that the transit system near the CBD had a higher impact than the properties that were away from the CBD. (Bartholomew & Ewing, 2011) a significant impact of transit-oriented development on property values was found by examining the proximity and accessibility parameters of transit stations and policies related to TOD. (Cao, 2010) concluded that the property values near station areas were higher than in the line area. Commercial and industrial values were also higher within the 1-mile radius of the station, along with residential property values. (Atkinson-Palombo 2010) analyzed the impact of light rail transit, which creates noise, congestion, accessibility, and traffic, which impact the land values. (Ge & Du, 2007) investigated the main variables influencing residential property values in the Auckland, New Zealand property market and ranked the variables using the Entropy method. The study used 18 independent and one dependent variables, and the top 5 most important attributes were the number of bedrooms and CPI. Location, land size, and CPI (construction). The availability of a garden is listed as the most negligible attribute that impacts property values, whereas the bedrooms have a higher impact. (Adebayo, 2006) described the relationship between urban infrastructure and its impact on property values. He concluded that infrastructure plays a vital role in determining property values. So, depreciation would occur in property values due to infrastructural degradation.

METHOD

The research methodology involved a detailed review of past research and a questionnaire-based survey via a Google form. Various papers and articles are searched through Google Scholar using the keywords property values, real estate pricing, land pricing, and infrastructure. With a filter of the time frame of 1990-2022, almost 200 papers are downloaded from Google Scholar and cross-referenced, out of which only 100 papers are relevant to the study. A questionnaire survey form is designed to get expert opinions about the factors that are shortlisted and categorized. One hundred twenty factors are shortlisted to 66 factors and clubbed together under ten major headings of attributes.

For this research, an expert is defined as an individual with a minimum of 10 years of experience in the area of academics, Real Estate professionals, Urban/ Transport Planner, Real Estate Developer and other people like real estate bankers, real estate investment professionals and economists who are actively involved in creating and visualizing urban fabric of the city (Shariff, 2015)(Ping, 2005)(Pham & Nguyen, 2019). Within the group of 15 experts for the Delphi survey, 4 are affiliated with the Real Estate industry. Furthermore, 2 experts have expertise in investment banking, 2 work as researchers and research associates in academia and real estate development, and 3 are experts in urban and town planning.

Analysis

The author identified 120 attributes that impact residential property values based on the literature studies. Then, the factors were shortlisted into 67 based on an expert survey, and the survey was based on a 5-point likert scale. The ranking is from 5 to 1, where five is highly appropriate, and one is highly inappropriate. With the questionnaire-based survey with experts, all the identified factors are clubbed together under the heading of 10 attributes, as in table 1. As per the expert survey, maximum importance was given to location, i.e., 16% follow connectivity and linkages, with 15%, environmental and demographics attributes having a negligible impact on the property values out of these 10 attributes, as shown in figure 1.

Connectivity & linkage

Under the heading of connectivity and linkage, according to the expert survey, accessibility to public transport is the primary factor, i.e., 23%. Accessibility to health facilities (21%) is followed by access to public amenities (19%), and the tiniest weight is assigned to accessibility to retail areas (18%), as shown in figure 2.

Demographics

As per the expert survey, income (31%) is the primary sub-factor under the demographic attribute, as shown in figure 3, followed by literacy rate (24%) and population and population change (21%).

Environmental factor

Water scarcity (32%) and pollution levels(32%) are the two main sub-factors under environmental factors, while heating is the least important factor, as shown in figure 4.

Infrastructural facilities

Under infrastructural facilities, physical amenities (26%)like water, sanitation, electricity, etc., are the significant sub-factors, followed by commercial areas/markets and the green regions, which impact the property values in any location, as shown in figure 5.

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Legal consideration

Under legal consideration, current and future land use is the main sub-attribute, which is 30%, then land title, i.e., 28%, followed by history of ownership (25%) and least to land scarcity (17%), as shown in figure 6

Location

Distance from transit stations like metro, bus, and airport has the highest weightage under this category, i.e., 29%, then the distance from cbd (27%), as shown in figure 7.

Policy and development control regulation

Figure 8 shows the subattributes of policy &

development control regulation, in which government policies play an important role.

Real estate dynamics

In real estate dynamics, respondents have indicated that the prime factor is the interest rate, which plays a vital role in property transactions, as shown in figure 9.

Socio- economic profile

As shown in figure 10, security and crime rate are the significant sub-factors under socio-economic attributes, followed by buyer income profile.

Structural attributes

Amongst the structural attributes, 28% of the respondents gave importance to the structure of the property, followed by the green area (17%), as shown in figure 11.

Table 1: List of main factors

Sr. No.	Parameter
1	Connectivity & Linkages
2	Infrastructure Facilities (Physical & Social)
3	Legal Consideration
4	Policy & Development Control Regulations
5	Location
6	Real Estate Dynamics
7	Socio Economic Profile
8	Structural Attributes
9	Demographics
10	Environmental Factors

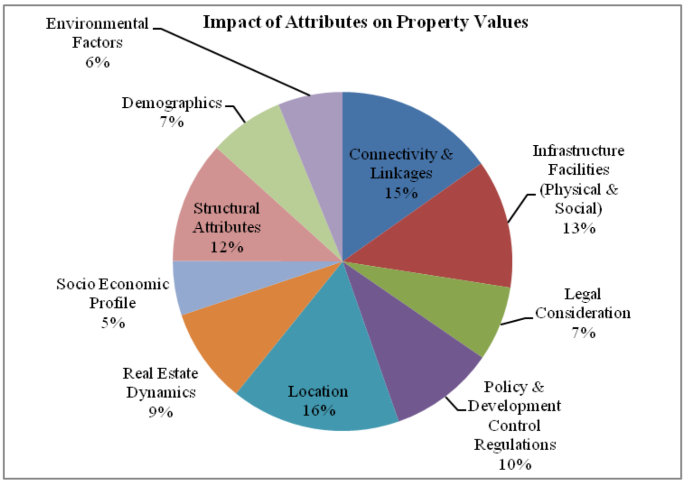

Figure 1 : List of Factors identified as per Literature Study

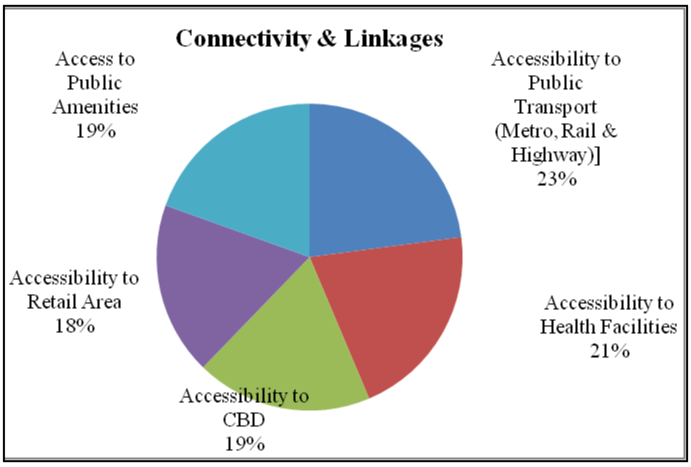

Figure 2 : Composition of sub-attributes under Connectivity & linkage

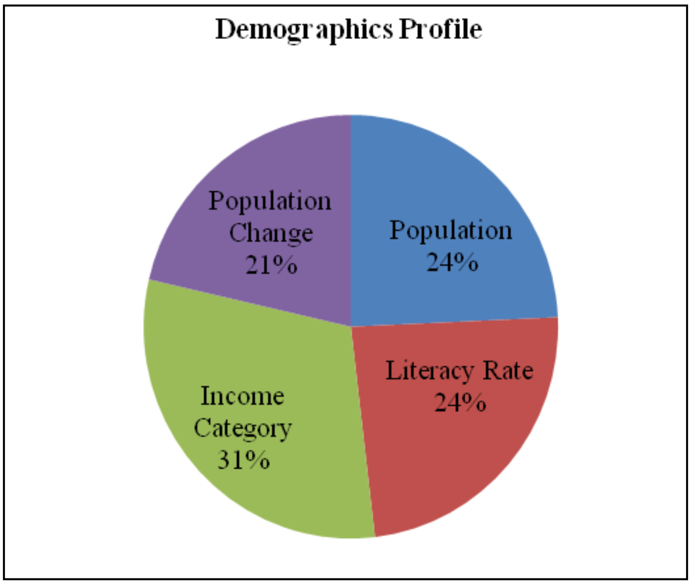

Figure 3 : Composition of sub-attributes under Demographic Profile

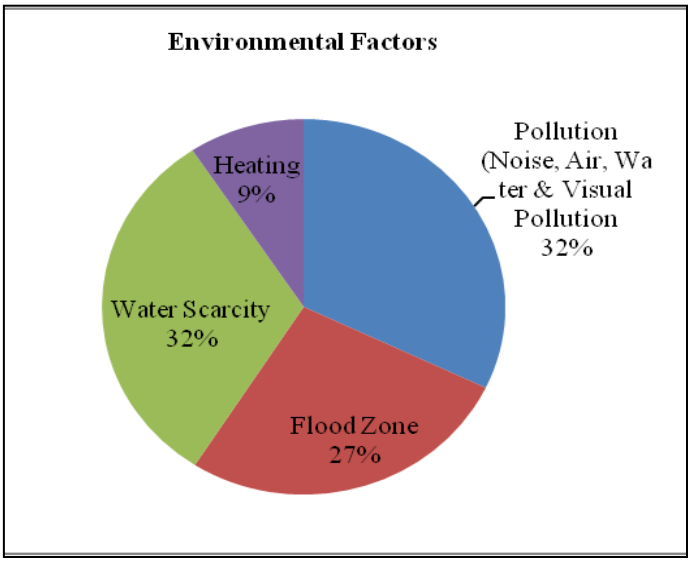

Figure 4 : Composition of sub-attributes under Environmental Factors

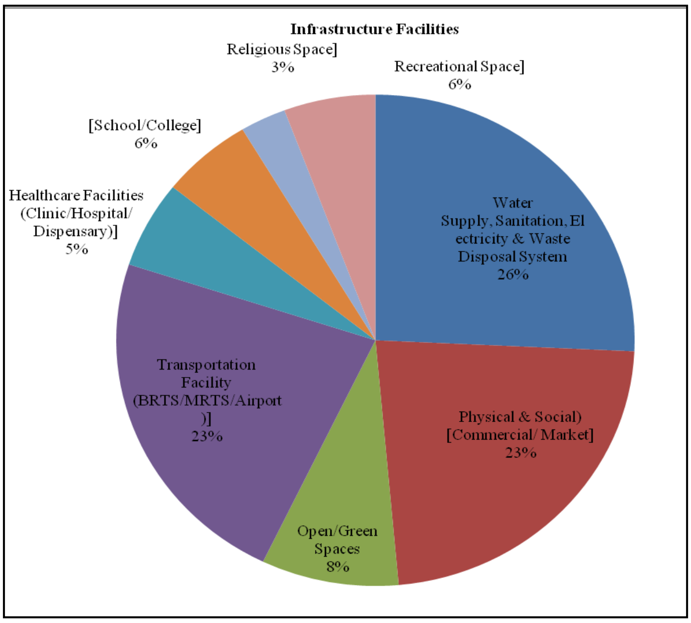

Figure 5 : Composition of sub-attributes under Infrastructure Facilities

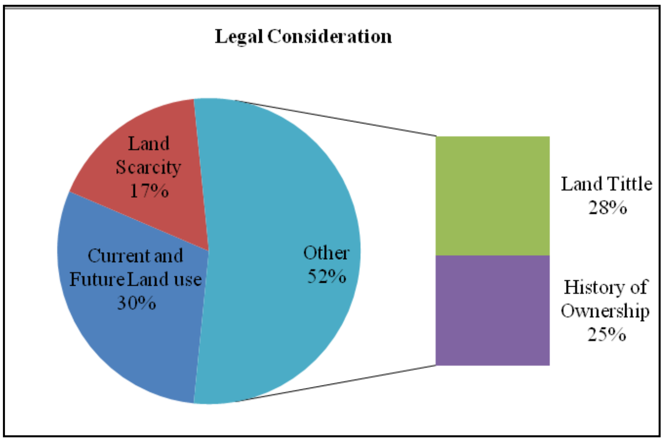

Figure 6 : Composition of sub-attributes under Legal Consideration

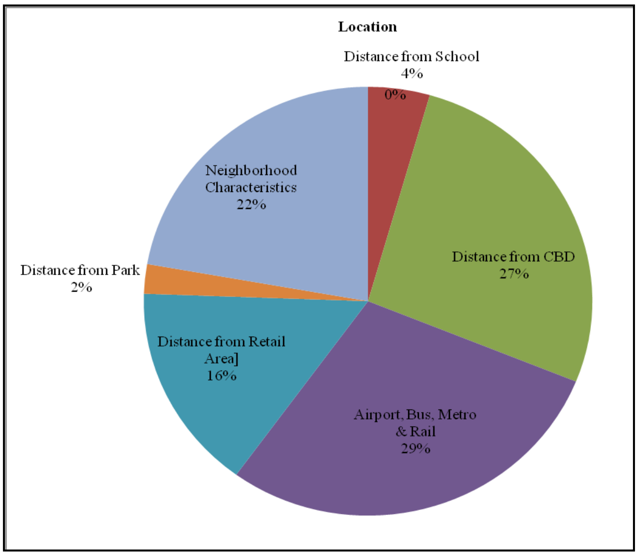

Figure 7 : Composition of sub-attributes under Location

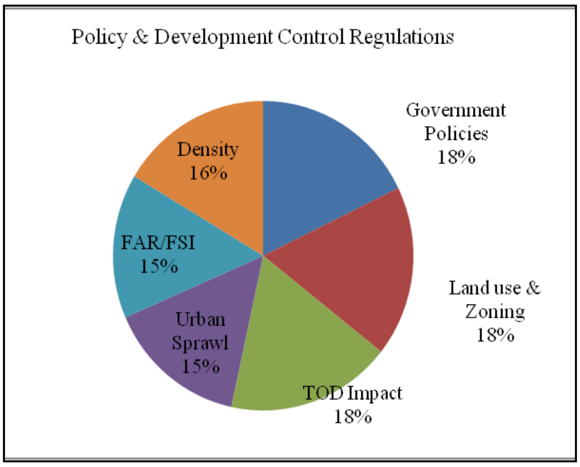

Figure 8 : Composition of sub-attributes under Policy & DC

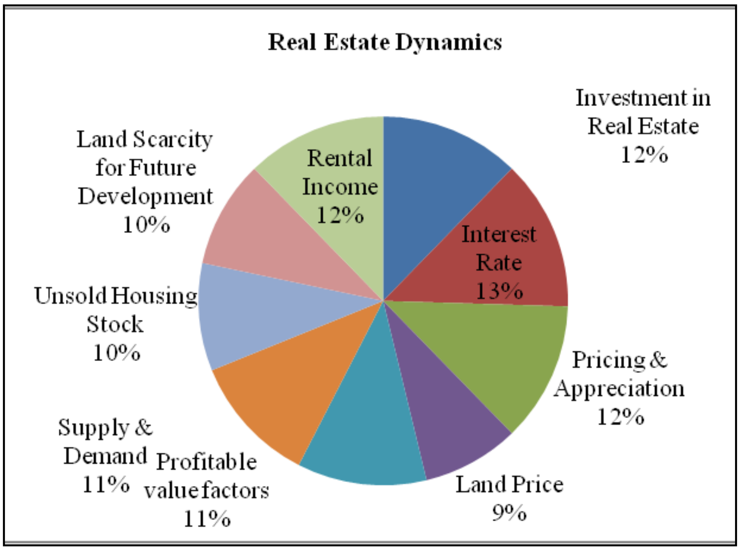

Figure 9 : Composition of sub-attributes under Real Estate Dynamics

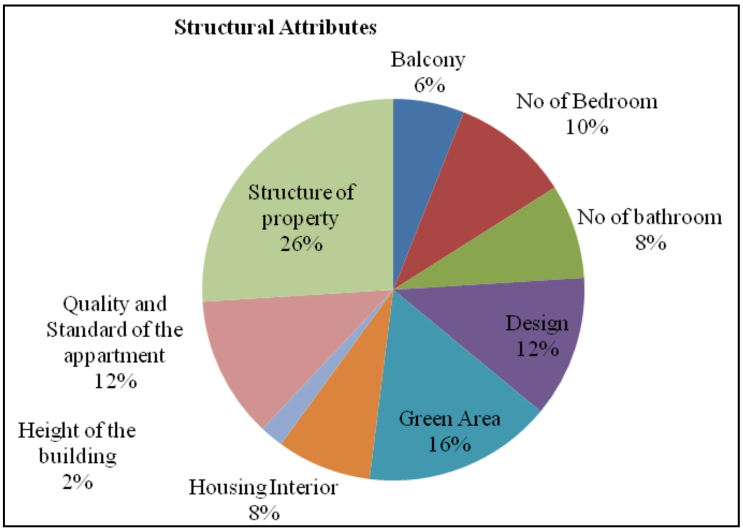

Figure 10 : Composition of sub-attributes under Structural Attributes

Based on the response received by the expert, weightage, and relative rank are calculated within the main attributes for the individual attributes and sub-attributes, as shown in Table 2.

Table 2: List of attributes and sub-attributes with weights and Relative ranking

S. No.	Attributes	Average of the weightage given by expert	Relative ranking	Sub Attributes	Average of the weightage given by expert	Relative ranking within Sub-factor
1	Connectivity & Linkages	3.2	2	Accessibility to Public Transport (Metro, Railway & Highways)	4.93	1
				Accessibility to Health Facilities	4.47	2
				Accessibility to CBD	4.00	4
				Accessibility to Retail Area	3.93	5
				Accessibility to Public amenities	4.2	3
2	Infrastructure Facilities (Physical & Social)	2.5	3	Water Supply, Sanitation, Electricity & Waste Disposal System	4.67	1
				Commercial/ Market	4.00	5
				Open/ Green/ Recreational Space	4.53	2
				Transportation Facility (BRTS/MRTS/Airport	4.40	3
				Healthcare Facilities	4.07	4
				School/College	3.80	7
				Religious Space	3.47	8
				Recreational Space	4.00	5
3	Legal Consideration	1.4	9	Current & Future Land Use	4.93	1
				Land Title	4.47	4
				History of Ownership	4.87	2
				Land Scarcity	4.80	3
4	Policy & Development Control Regulations	2.1	5	Government Policies	4.87	1
				Land use & Zoning	4.87	1
				Property Type	4.80	4
				TOD Impact	4.87	1
				Urban Sprawl	4.73	6
				FSI/FAR	4.73	6
				Density	4.80	4
5	Location	3.3	1	Distance to school/health	4.13	3
				Distance from CBD	3.87	4
				Distance from Public Transport (Airport, Bus, Metro & Rail	4.33	2
				Distance from Retail Area	3.87	4
				Distance from Park	3.87	4
				Neighborhood Characteristics	4.47	1
6	Real Estate Dynamics	1.9	6	Investment in Real Estate	4.87	2
				Interest Rate	4.93	1
				Local Market Trend (Pricing & Appreciation)	4.87	2
				Land Price	4.60	9
				Profitable value factors	4.80	5
				Supply & Demand	4.67	6
				Unsold Housing Stock	4.67	6
				Land Scarcity for Future Development	4.67	6
				Rental Income	4.87	2
7	Socio Economic	1.4	8	Job Opportunity	3.60	7

S. No.	Attributes	Average of the weightage given by expert	Relative ranking	Sub Attributes	Average of the weightage given by expert	Relative ranking within Sub-factor
	Profile			Buyer's Income	4.60	3
				Economic	4.13	4
				Travel Cost & Cost	3.87	5
				Employment	3.67	6
				Car Ownership	2.87	8
				Cultural factor	2.20	10
				Migration	2.33	9
				Crime	4.73	1
				Security	4.73	1
8	Structural Attributes	2.3	4	Balcony	4.13	7
				No of Bedroom	4.33	5
				No of bathroom	4.33	5
				Design	4.40	4
				Green Area	4.53	2
				Housing Interior	3.20	8
				Height of the building	3.07	9
				Quality and Standard of the apartment	4.47	3
				Structure of property	4.87	1
9	Demographics	1.5	7	Population	4.00	3
				Literacy Rate	4.07	2
				Population Change (Growth Rate)	4.60	1
				Income Category	3.93	4
10	Environmental Factors	1.3	10	Pollution (Noise, Air, Water & Visual Pollution	4.6	2
				Flood Zone	4	4
				Water Scarcity	4.53	3
				Heating	4.67	1

RESULT

As per the analysis done by the given weightage and relative ranking method, location is the main attribute that impacts the property values, with a higher weightage of 3.3 and 1 relative ranking. Neighborhood characteristics (4.47) have the highest weightage within sub-factors, followed by the distance from public transport(4.33). Connectivity and linkage have a weight of 3.2 and a relative ranking within 10 attributes of 2. Availability to public transport has the highest relative ranking out of 5 subfactors, and accessibility of the retail area has the least, i.e., 5, with a weightage of 3.93. Infrastructure facilities (Physical and social) have a 2.5 weightage and a relative rank of 3, followed by structural attributes, real estate dynamics, demographics, and socioeconomic profile. Infrastructure facilities (Physical and social) have a relative ranking and weightage of 2.5. Environmental factors have the lowest weightage and ranking, as shown in Table 3.

CONCLUSION

All these factors impact property values in some intensity, but the study shows that location, followed by connectivity and linkages, are the major factors that significantly impact property values. Properties in desirable locations tend to have higher values due to their proximity to amenities, schools, shopping centers, and other conveniences. Additionally, properties in areas with better connectivity, easy access to public transportation, good job opportunities, and low crime rates often command higher prices. Regarding the availability of infrastructure, MRTS has more impact on property value than other available infrastructure like BRTS. Metro presence has increased the achievable FSI/FAR, resulting in higher real estate values. DCR (Development Control Regulation) is very important in terms of the applicability of TOD. So, Government policies play a vital role in the infrastructure, which directly/indirectly impacts property values. Structural attributes of a property also influence its value. The size, layout, number of bedrooms and bathrooms, and the property's overall condition can impact its market worth. Properties that require minimal repairs or renovations are generally more appealing to buyers and may command higher prices. When assessing real estate values, it is essential to consider factors such as location desirability, connectivity and linkage options, structural attributes like size and condition, infrastructural facilities available nearby (utilities), and socio-economic indicators (job opportunities.

CONFLICTS OF INTEREST

The authors declared no conflict of interest.

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Santhal tribal houses evolving in context to their unique sociocultural identity and prevailing climate

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Abstract - Santhals are one of the largest ethnic groups in India, spread across three states of India, Jharkhand, West Bengal, and Odisha. They are a culturally expressive tribe and are well-known for their skilful dance forms, and music as well as their aesthetic but simple artistic designs and patterns on the walls of their huts. Their vernacular dwellings are expressions of their cultural richness, as well as responding to the prevailing hot tropical climate. This paper discusses how the Architecture of the Santhal tribe is reflective of their cultural ethos, prevailing climatic conditions, and unique aesthetic senses. How their building planning principles and building materials used are contextual to culture and climate is explored. The architectural styles followed by the Santhal tribes in East Singhbhum district in Jharkhand and Purulia district in West Bengal both falling under the 'Warm-Humid' climate as per the National Building Code, 2016 Climate Classification, is discussed. Apart from culture and climate, how their daily activities have also impacted the evolution of their dwellings has also been discussed. The paper concludes after analysing the evolution of Santhal Architecture in the context of culture and climate and stresses the imperative need to preserve the architectural traditions of the dwellings for the future generations of the Santhal tribal population who migrate to urban areas for education and occupation purposes. There is a need to implement the same essence in modern-day residences by reinterpreting the vernacular principles in a contemporary manner to make them more culturally and climatically contextual, which is reflective of the essence of the ways of living and cultural ethos of the Santhal Tribes, at the same time being at par with contemporary architectural standards and amenities.

Keywords: Santhal Tribe, Vernacular Architecture, Culture, Climate, Aesthetics, Building Materials.

INTRODUCTION

The Santhals are one of the largest ethnic groups in India and the largest group of Schedule Tribes, spread across three states of India, Jharkhand, West Bengal, Bihar, and Odisha. The Santhals were originally nomads before they chose to settle in the Chotanagpur plateau. By the end of the 18th century, a noticeable concentration of Santhal communities had happened in Jharkhand, as well as in a few parts of West Bengal and Odisha. (Figure 1) Besides primary livelihoods of agriculture and hunting to a lesser extent, they are well known for their skilful dances and music. They are a culturally expressive tribe and are well known for their skilful dance-forms, and music as well as their aesthetic but simple artistic designs and patterns on the walls of their huts. They are well connected to their traditional practices and roots. Being nature-worshippers, Santhal tribes pray at the sacred groves and have festivals related to the same. Santhals take part in community folk songs and dances. They play musical instruments like kamak, dhol, sarangi, and flutes. Art finds expression in their homes, with many walls having artistically done decorations, and some having a particular three-color pattern on their outer walls. The bottom portion is painted with black soil, the middle with white and the upper with red.

Figure 1 : Location of Santhal settlements in small pockets of Jharkhand, Bihar, West Bengal, and Orissa. (Source: Bethany World Prayer Centre)

As per Archer (1974), Santhals are historically and locally renowned for their neatness, orderliness, and workmanship in constructing houses and organizing village settlements. Archer (1974) admired the neatly finished mud walls and clay-tiled roofs of the vernacular dwellings of the Santhal Tribesmen. He further observed that among all types of tribal architecture that he had observed in the eastern part of India, these dwellings were most tidily done with a sense of orderliness and aesthetics prevalent in their built form.

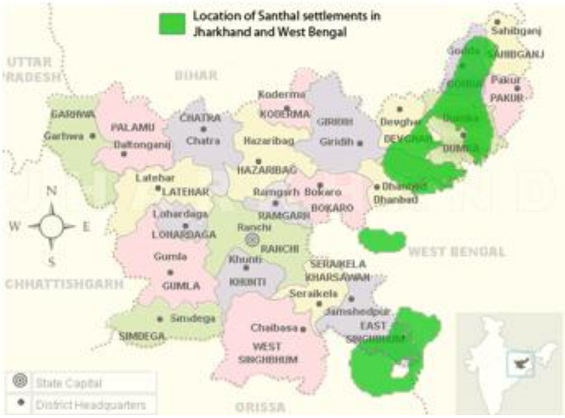

Figure 2 : Location of Santhal settlements in Dumka, Jharkhand (East Singhbhum district) and West Bengal (Puruliya district).

Study area

The study area for this paper is Dumka in East Singhbhum district (Jharkhand) and neighboring Purulia in Purulia district (West Bengal). (Figure 2) Jharkhand is a state located in the eastern part of India. The imaginary latitude line, 23.5 degrees north (Tropic of Cancer), passes through very near its capital, Ranchi. Bordering states to it are West Bengal and Odisha. East Singhbhum District is situated at the extreme corner of the southeast region of Jharkhand with headquarters at Jamshedpur. East Singhbhum District is located at a longitudinal extent of 86 degree 4 minutes to 86 degree 54 minutes east and a latitudinal extent of 22 degrees 12 minutes to 23 degrees 1 minute north. In the Kolhan area of East Singhbhum, the sizeable population of Santhals and a few other smaller tribes are mostly found. They are a pastoral community whose folk literature and songs have been preserved from generation to generation by repetition. It is a part of the Chota Nagpur Plateau of igneous, sedimentary, and metamorphosed rocks. The culture of East Singhbhum District is tribal as

it has a sizeable tribal population. They are deeply rooted in their cultural ethos. They have their dialect, social rules, traditions, beliefs, and festivals. (https://purulia.gov.in/folk-culture/)

Purulia district is one of the twenty-three districts of West Bengal state in Eastern India. Purulia lies between 22.60 degrees and 23.50 degrees north latitudes and 85.75 degrees and 86.65 degrees east longitudes. Daripa (2018) in his study had surmised that the villages of Purulia district are dominated by rural tribal people. They have their unique lifestyle. Santhal tribe men of this district have distinct age-old social systems, cultural traditions, customs, values, lifestyles, and languages. They have their unique dance form called Chau dance. They also decorate the walls of their homes with artwork.

Climate found in study area

The National Building Code, 2005 (NBC) classifies the climate found in the southern most of Jharkhand including East Singhbhum district, and the south-eastern part of West Bengal including the Purulia district as the 'Warm-Humid' climate. (Figure 3) In warm and humid climate, the diffuse fraction of solar radiation is quite high due to cloud cover, and the radiation can be intense on clear days. The dissipation of the accumulated heat from the earth to the night sky is generally marginal due to the presence of clouds. Hence, the diurnal temperature variation is quite low. In summer, temperatures can reach as high as 35 º- 40 º C during the day and 25 – 30 º C at night. In winter the maximum temperature is between 25 to 30 ºC during the day and 10 to 20 ºC at night. Although the temperatures are not excessive, the high humidity causes discomfort. An important characteristic of this region is the relative humidity, which is generally very high, about 70 – 90 % throughout the year. Precipitation is also high, being about 1200mm per year, or even more. The high humidity encourages abundant vegetation in these regions. The wind is generally from one or two prevailing directions with speeds ranging from extremely low to very high. Natural Ventilation, as long the temperature of the air is not too high, is desirable in this climate, as it can cause sensible cooling of the body.

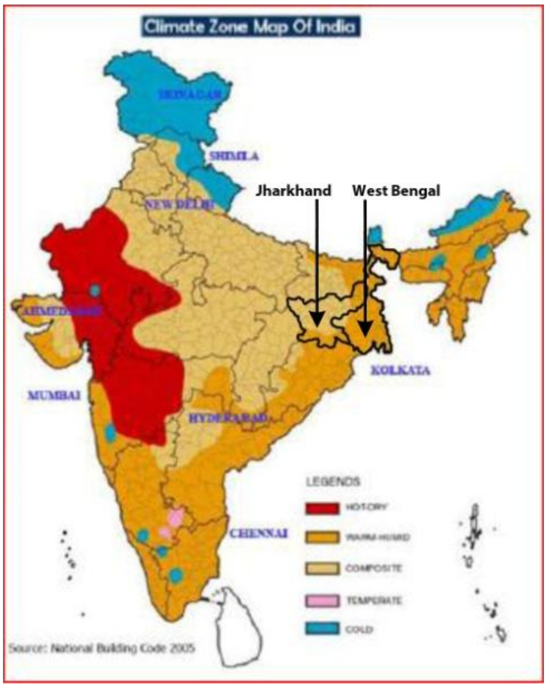

Figure 3 : The National Building Code (2005) classifies the climate of the study area as warm-humid.

Types of Santhal dwellings

These dwellings are usually built with mud and usually have mostly clay-tiled roofs, (Figure 4 & 5) and in some cases thatched roofs. Often their walls have colourful artistic patterns on them. (Figure 6)

Figure 4 : Typical dwellings having mud walls and tiled roofs. (Source: Author)

Figure 5 : The over-hanging eaves of the thatch roof. (Source: Author)

Figure 6 : Artistic patterns on wall of Dwellings. Source:(https://in.pinterest.com/pin/132645151517266669/ https://in.pinterest.com/pin/310678074311095486/)

Santhal dwellings in and around Dumka in the East Singhbhum region often comprise rooms organized around a courtyard. (Figure 7) The interior spaces are usually used as cooking areas, sleeping areas, space for sheltering cattle, for storing grain, and worship rooms. The interior spaces are meant for private use by the family only. Outsiders are met in the courtyard or the space in front of the house. Quite often these houses have a large backyard as well where washing, storage of agricultural produce, storing hay, and growing of vegetation takes place. (Figure 8)

Figure 7 : Typical Courtyard-type Santhal house in East Singhbhum, Jharkhand at present. (Source: Author)

Figure 8 : Interior space in Santhal house in East Singhbhum, Jharkhand at present.
(Source: Author)

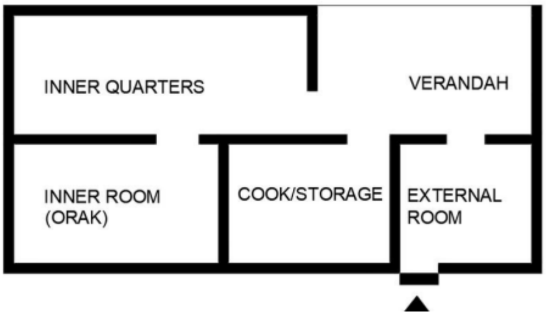

Figure 9 : Plan of the rectangular house
(Source: Author)

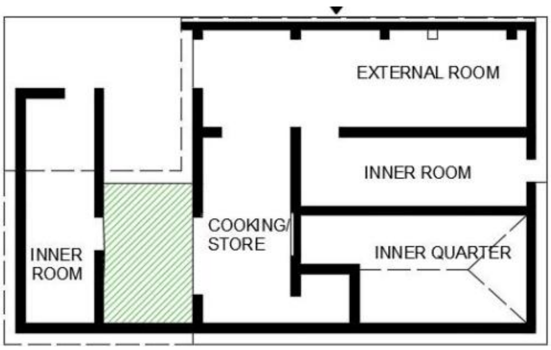

Figure 10 : Plan of the Aath-Chala house
(Source: Author)

Figure 11 : Elevation of the Aath-Chala house. (Source: Author)

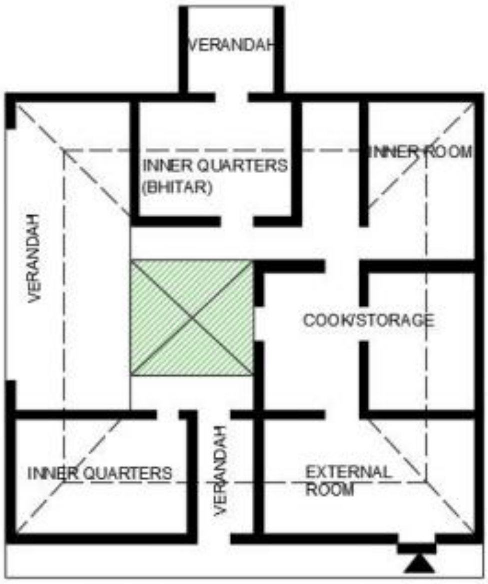

Figure 12 : Plan of Courtyard house (Source: Author)

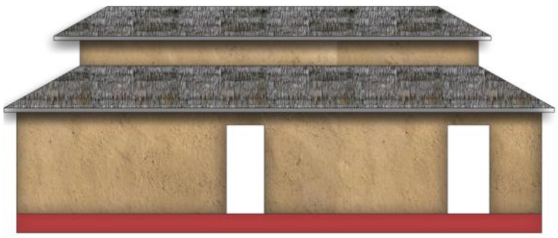

Figure 13 : Elevation of Courtyard house. (Source: Author)

Presently three types of mud house variations are found across the two areas of East Singhbhum and Purulia districts. They are the Rectangular House, Aath-Chala House, and the Courtyard House. (Bharat, 2014)

These three layouts (single rectangular form, *aath-chala,* and courtyard houses) comprise the range of Santhal architectural forms in the East Singhbhum and Purulia regions. The single rectangular type houses have a single volume (that may be internally divided into two spaces). Within the volume, one finds the inner room and spaces for sheltering animals. In these houses, more household activities are located indoors. (Figures 9,14 and 15)

Figure 14 : Rectangular Unit
Source: https://www.alamy.com/tribal-mud-houses-and-courtyard-santhal-tribe-hardhekitand-village-image67882493.html

Figure 15 : Traditional Rectangular Unit with art work on walls. (Source: Clicked by Author at Indira Gandhi Manav Sangharalaya, Bhopal)

This type of layout is particularly built by families who require much less space as compared for other families. As compared to wood, bamboo and leaves that are usually procured from nearby forest areas, earth used for constructing the walls of the buildings is usually sourced out from designated parts of the village, and in many cases from people's own backyards. (Figure 16)

Figure 16 : Mud lumps sourced out from site itself (Source: Gautam, A., 2008)

The *aath-chala (*eight-roofed) type has a central volume and a verandah-like space all around it. *Aath-chala (vernacular)* means 'eight roofs' when translated to English language. This type of house is known as *aath-chala* on account of the roofs above the central volume and the spaces on all sides are so arranged that the roof has eight sloping sides. This enables such dwellings to have a nicely built form of massing. The central volume of the *aath-chala* has *inner private areas* and is also used as a storage area. However, by the end of the nineteenth century generally, *aath-chala* houses were no longer being built and courtyard houses were becoming increasingly common. The *aath-chala* huts were more common in Puruliya district in Bengal and the villages along the Bengal border because the *aath-chala* houses are a vernacular form of Bengali house typology. They were likely a source of inspiration for the well-to-do Santhals who typically built these larger and more permanent dwellings for themselves. (Figures 10,11 and 17)

Figure 17 : Massing in elaborate *aath-chala* huts of Puruliya (Source: Clicked by Author at Indira Gandhi Manav Sangharalaya, Bhopal)

Courtyard houses are formed of some single rectangular units that are organized around a central courtyard. In this case, different *rectangular units* contain different activities like storage, cooking, sleeping areas, and sheltering animals. This type of house is well-planned concerning the size and differentiation of activities within spaces. The permanent nature of the sturdily constructed houses indicates an established agriculturist mode of living. The courtyard type dwellings are either individual units stacked around a courtyard or a consolidated built mass having a central inward-looking courtyard. (Figures 12,13,18 and 19)

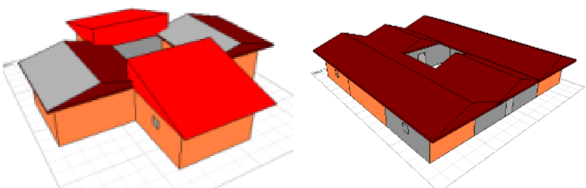

Figure 18 : Two types of Courtyard house patterns followed. (Source: Author)

Figure 19 : Courtyard houses from single units. (Source: Author)

Discussion

In this section, the evolution of Santhali Architecture interwoven into the fabric of cultural practices as well in response to the prevailing warm-humid climate is briefly discussed.

- Cultural Richness and Aesthetics.
- Planning Principles.
- Climate-responsiveness.
- Building Materials and techniques used.

Cultural Richness and Aesthetics.

Santhals are a culturally expressive tribe and are well-known for their skilful dance forms, and music as well as their aesthetic but simple artistic designs and patterns on the walls of their huts. Their vernacular dwellings are expressions of their cultural richness. Out of the three typologies of Santhal village house types identified, the *aath-chala* house types stand out as showing a distinct architectural character with an interesting play of built-mass heights, with three distinct levels of building canopies. The main entrance to the hut is tastefully done, with the gateway creating an architectural focus. (Figure 20) The different levels of thatched roofs create an interesting rhythm and create a sense of asymmetrical balance with the asymmetric masses combining to create a complete sense of overall harmony. The rectangular huts have beautifully done artwork on the external walls. (Figures 21 and 22) The unique art patterns on the external walls of the dwellings are part of the cultural heritage of the Santhals. These artworks, so simple yet so vibrant and unique lend a breadth of fresh air to these built forms, as well as make these dwellings a part of living cultural heritage, wherein everyday life integrates seamlessly into the cultural expressions of the Santhali tribes.

Figure 20 : Well-defined gate structure at the main entrance of Aath-Chala house. (Source: Author)

Figure 21 : Vibrant organic dye colours used on walls (Source: Author)

Figure 22 : Art works on external walls. (Source: Author)

Planning Principles

There is a hierarchy of spaces followed, starting from the entry into a semi-private zone at the entry foyer area of the dwelling, where guests and outsiders are welcome, gradually transitioning into more private inner family rooms with the intermediary courtyard space, which is used for a variety of activities placed in between as a threshold and semi-private or private (differing case to case based on the type of usage, family structure, family customs, etc) buffer space. This is true for both the courtyard as well as the eight-roofed houses. In courtyard houses, one moves from the front street through a door to enter the courtyard. Consequently, it becomes a relatively more interior space. The courtyard houses are more inward-looking as compared to the *aath-chala (*eight-roofed) houses which have a more outward plan with the inner areas opening into continuous semi-open areas. The rectangular huts are quite straightforward functional basic spaces, which is what they are intended to be. (Figures 9,10 and 12)

Climate Responsiveness

The longer sides of these dwellings are usually aligned along an east-west orientation which is the preferred orientation in these parts, so that the shorter sides of the buildings are exposed to the west and east, the longer sides facing north and south. The *Aath-Chala* huts allow for adequate shade to some semi-covered areas and the open plan with the different parts of the dwelling opens onto an open courtyard. (Figures 23and 24) It allows for adequate wind flow into the dwelling's rooms in summer. In winter, the semi-open areas allow the inhabitants to tap into the south-side sunrays. In the courtyard type of dwelling with a central courtyard, a certain amount of relief is obtained in summer during the evenings, but the amount of relief obtained is limited due to the lack of air movement inside the courtyard closed from all sides by built mass. The inward-looking plan fails to tap the summer-time evening breeze into the living areas.

Figure 23 : Partially shaded courtyard areas in the Aath-Chala houses. (Source: Clicked by Author at Indira Gandhi Manav Sangharalaya, Bhopal)

Figure 24 : Variations of courtyards and built mass in Aath-Chala houses. (Source: Clicked by Author at Indira Gandhi Manav Sangharalaya, Bhopal)

Building Materials and techniques used

The building materials used in the santhali huts are mud for the walls and clay tiles and in some cases thatch on bamboo/timber framework as the roof. (Figure 25) Mud is well known as a material with good heat capacity, which keeps the inside of the huts considerably cooler in the peak of summer-daytime and warmer in winter-night-time. However, there was scope for a greater amount of ventilation in the humid part of the year. The additional insulation that the bamboo wattle framework provides is helpful to keep out the tropical heat inside the dwellings and enhances indoor thermal comfort in the peak of summer. (Figures 26,27 and 28) Thatch is also a well-known insulating material that keeps the inside of these huts' cooler in summer and warmer in winter. (Figure 25) The overhanging roof eaves typically found in these dwellings allow for shading in summer daytime and in the case of the *aath-chala* houses and courtyard-type houses shade the courtyards partially, there keeping the courtyards cooler.

Figure 25 : Thatched roof with over hanging eaves and mud walls keeping the inside of the huts cool in summer. (Source: Author)

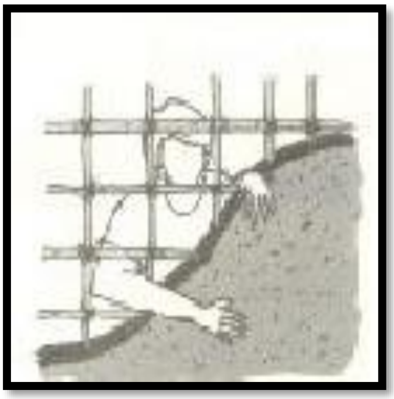

Figure 26 : Wattle and Daub Construction. (Source: Uthaipattrakul, 2004)

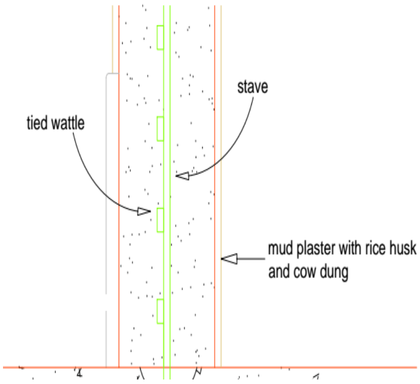

Figure 27 : Wattle and Daub wall section. (Source: Author)

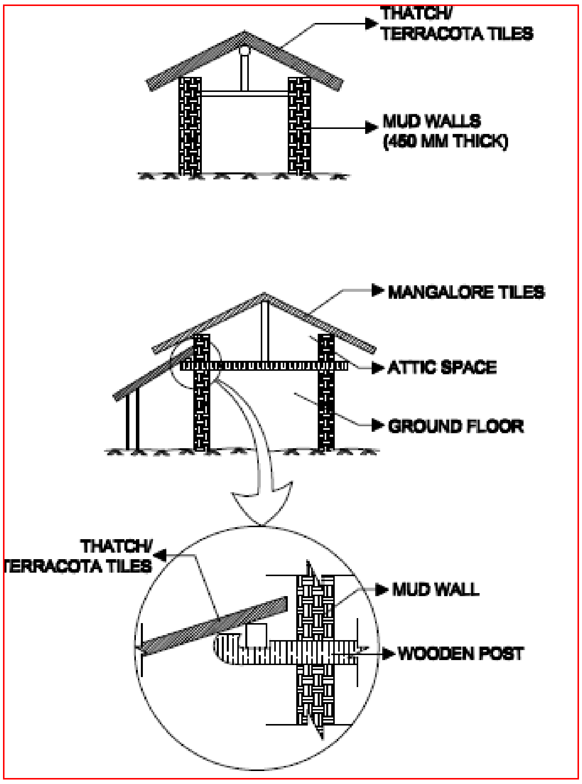

Figure 28 : Wattle and Daub Wall Section. (Source: Author)

CONCLUSIONS

There is an imperative need to preserve the architectural traditions of the dwellings for the future generations of the Santhal tribal population who migrate to urban areas for education and occupation purposes. There is a need to implement the same essence in modern-day residences by reinterpreting the vernacular principles in a contemporary manner to make them more culturally and climatically contextual, which is reflective of the essence to the ways of living and cultural ethos of the Santhal Tribes, at the same time being at par with contemporary architectural standards and amenities.

Some 'Aath-chala' houses provide good examples of innovative massing of built mass and a transition from closed spaces to open spaces. The open planning also allows it to access the south-side summer-time breeze during the harsh summer. It is imperative to preserve the architectural traditions of the '*aath-chala'* dwellings and implement their planning principles in modern-day residences to imbibe modern constructions with a vernacular touch and to make them more bio-climatic as well. Some youngsters having tribal backgrounds are migrating to cities after getting better quality education than their ancestors and settling down there. Given their strong roots in their culture, in the long run, they would be comfortable residing in homes that imbibe the architectural essence of their ancestral dwellings, as has been discussed in this paper. There is need to ensure that the dwellings designed for the next generation well to do youngsters should not be divorced from their intrinsic cultural context at the same time being contemporary. Valuable lessons can be learnt from the rich cultural and architectural variety of the existing Santhali Dwellings.

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Exploring the Significance of Multi-sensory Architecture

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Abstract— Most studies and research on architecture focus on functionality and aesthetic elements of space and conclude with various outcomes but the fact that architecture is a perceived manifestation of the realm of existence of life is often ignored. Architecture is encountered, understood, absorbed, perceived, and assessed by users through the inclusion of five human senses which are vision, hearing, touch, taste, and smell. The focus of this research is to understand and evaluate the detailed features of multisensory architecture and its huge influence on spatial perception, the built environment and the relation between architecture, the human body and memory. The aim is to study immersive spaces and elements that harmoniously integrate visual, auditory, tactile, and environmental elements, fostering heightened sensory experiences and emotional connections. The research aims to study the influence of multi-sensory architecture on human brain and understand the relationship between memory and sensory experiences. The advancement of technologies continues to evolve our interactions with our surroundings which further expands and makes the study of multisensory architecture important for us. Since research on modern architecture focuses on the importance of multimodal design, the in-depth analysis of importance of multisensory elements in built environment and their impact on human perception is still missing. This study is done to fill that void by understanding multisensory perception and the relationship between built environment and human perception. The study contributes to the potential of future of multisensory architecture. The objective of the research is to understand multisensory design principles in detail, to evaluate multisensory experiences, to understand cultural and contextual considerations, to understand user centered design, to understand relationship between memory and sensory experiences, and to understand merge of different senses. The study aims to examine current trends, technologies, and innovative approaches. To achieve these objectives, the research involves a diverse methodology. Some questionnaire surveys are done to capture the subjective experiences related to multisensory architectural elements across various built environments. A comprehensive review of existing research is done to gather theoretical foreground. Case studies are done to extract examples and physical insights from the real world. This research proceeds to a conclusive understating of multisensory architecture, spatial perception, human experience in a built environment and the relationship between architecture and memory.

Keywords: Sensory Interaction; User Engagement; Multisensory perception; Built Environment; Multisensory Design

INTRODUCTION

Multisensory architecture is the art of creating spaces that engage not just one, but all our senses. Beyond mere functionality and aesthetics, it is about designing environments that speak to our emotions, memories, and instincts. In a world often dominated by visual aesthetics, multisensory architecture reminds us that the built environment can be a symphony of sensations. (zumthor, 2010) As we step into a multisensory architectural space, our eyes are drawn to vibrant colors and harmonious shapes. The play of light and shadow creates a dance that transforms the mundane into the magical. Simultaneously, our ears are serenaded by carefully crafted acoustics, enhancing our connection to the environment. Our hands and feet navigate textures, from the smoothness of polished wood to the coolness of stone, grounding us in the physicality of the space. Inhaling the air, we detect subtle fragrances, while the climate envelops us in a comfortable embrace. (Thoreau, 1854). Multisensory architecture is not just about the sensory feast; it is about shaping experiences. It is about designing libraries that hush the world outside, homes that cocoon us in comfort, and parks that echo with laughter. It is about recognizing that every space tells a story, one that unfolds through our senses. (Mashley, 2017) In this journey, we will uncover the essence of multisensory architecture. From its historical roots to its contemporary relevance, we will explore how it transforms spaces into living, breathing entities. We will discover the artists who masterfully blend sensory elements and the technologies shaping the future of design. Together, we will step into a world where architecture is not just a sight to behold, but a symphony for all our senses to savor. This research aims to explore the intricacies of sensory architecture, examining the integration of visual aesthetics, tactile experiences, auditory sensations, and environmental factors in architectural design. By addressing this challenge, the study seeks to provide insights into creating spaces that not only meet functional requirements but also elicit emotional connections and enrich the quality of human life within built environments.

LITERATURE REVIEW

Architecture is not just about looks; it shapes how we live. Like the bones and muscles in our body support movement, architecture provides spaces for our activities. Architects organize what we see, hear, touch, smell, and taste, creating a rhythm that connects with people. It goes beyond aesthetics, influencing our emotions and well-being. (Pallasmaa, Encounters 1: Architectural Essays, 2005). Architecture anchors us in the world, giving us a sense of belonging and direction. It helps us understand where we are and connects us to the unique character of a place. In simpler terms, it is a fundamental element that grounds us and shapes our connection to the world (Norberg-schulz, Architecture: Presence, Language and Place, 1996). Our bodies are the center of our senses, shaping how we experience the world. Our senses, connected to our physical structure, constantly gather information, influencing how we perceive and remember places. They serve as a lens through which we understand the world, including its form, space, and architecture, enriching our sense of self. In exceptional architecture, space, matter, and time merge into a unified dimension, influencing our awareness. Architecture is the art of aligning ourselves with the world through our senses (Pallasmaa, Encounters 1: Architectural Essays, 2005). Our bodies are at the core of our world; we perceive the environment from within our immediate space or surroundings (Rodaway, 1994).

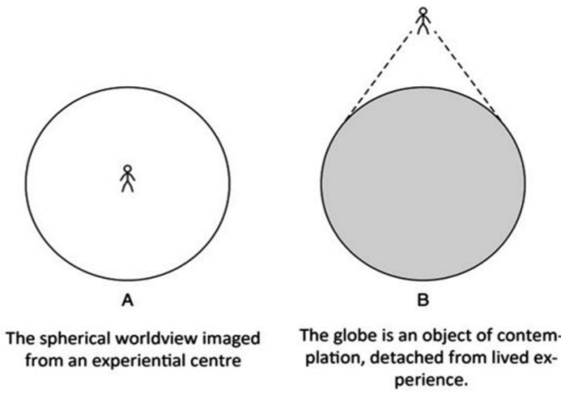

Figure 1 : The environment as life world (A) and as globe (B), reference: (Rodaway, 1994)

Need for design for senses- How a place feels creates its meaning and a personal connection. In our visually focused world, considering the sensory experience makes architecture more meaningful. People feel spaces differently, making it hard for architects to create universally meaningful places. Architects rely on intuition as they cannot predict how someone will feel. Our senses shape our experience, creating meaning and connection. In today's visually focused world, highlighting the role of architectural language is crucial. Investigating sensory involvement is key for a richer architectural language. (Choudhury, 2016).

Designing for the senses is crucial for how we understand events.

- Exteroceptive senses involve external stimuli (ears, eyes, skin, tongue, and nose).
- These senses contribute to cognitive processes and our desire to sense the external world.

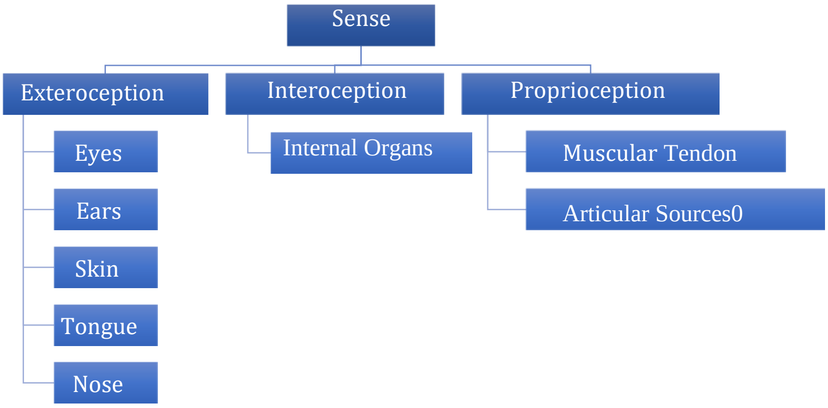

Figure 2 : Sensory Perception: Mapping How Our Body Interprets the Senses, Reference: (https://nikolaussucher.github.io/biology-text/sensation-receptors-organs-and-systems.html)

History of Senses- The "Eye of Horus" in Ancient Egypt symbolized six senses: touch, taste, hearing, thought, sight, and smell. Touch was considered most important. During the Renaissance, senses were associated with elements like fire, air, vapor, water, and soil. (Pallasmaa, 1996). Today, the five senses are often ranked, with vision considered the most important and touch at the bottom (Mashley, 2017). Researchers typically study one sense at a time, simplifying the investigation—for example, examining how changing lighting color affects individuals (Bellizi, 1993). In the Renaissance, senses were hierarchically structured, with sight as the highest and touch as the lowest. Visual experiences were known for a strong tactile quality in the Baroque and pre-modern periods (1800-1880 AD). The modular approach to the mind gained popularity in the late twentieth century (Fodor, 1983). Despite the inherently multisensory nature of environments, environmental psychologists have only recently explored how senses interact (Bille & Sørensen, 2018). In the Renaissance, reason was closely tied to vision, but Descartes acknowledged touch as a more reliable experience due to its intimate interaction with the object (Pallasmaa, 1996)

Five major senses- Understanding architecture and the senses means focusing on perception, always shaped by our traditional five senses: sight, hearing, touch, taste, and smell (Choudhury, 2016).

Vision

Our sense of sight, like a biological camera, captures and translates images into nerve impulses for the brain, allowing us to perceive and interpret our surroundings. (Osei, 2014) The eye, crucial in our perception, is often the first sense considered in architecture, which tends to prioritize visual appeal without accounting for the entire body. Our understanding of the world heavily relies on vision, and in the Middle Ages (373-1453 AD), Thomas of Aquinas expanded the concept of sight to include other senses and intellectual cognition. (Adler, 1968). Modernists like Le Corbusier emphasized vision's importance, stating "I exist in life only if I can see" (Goffman, 1959). While sight paints a picture, sound, touch, taste, and smell embody life itself (Sullivan, 1975). Shifting focus frees the eye from historical dominance; peripheral vision defines our experience, and focused vision reveals reality. Colors have three characteristics: brightness, saturation, and hue. Angular objects subtly impact emotions; round shapes create a lively atmosphere. Angles, especially pointing downward, may feel threatening. Furniture shapes, like circular tables, influence a room's mood. Ceiling height affects our responses. Shifting focus liberates the eye; daily experiences are shaped by peripheral vision. Focused sight reveals reality, while peripheral vision immerses us (Pallasmaa, 2005)

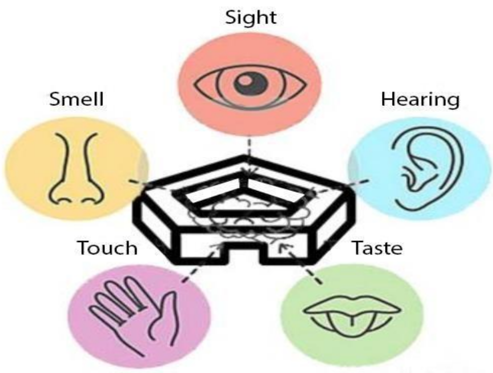

Figure3 : Five Senses, (Choudhury, 2016)

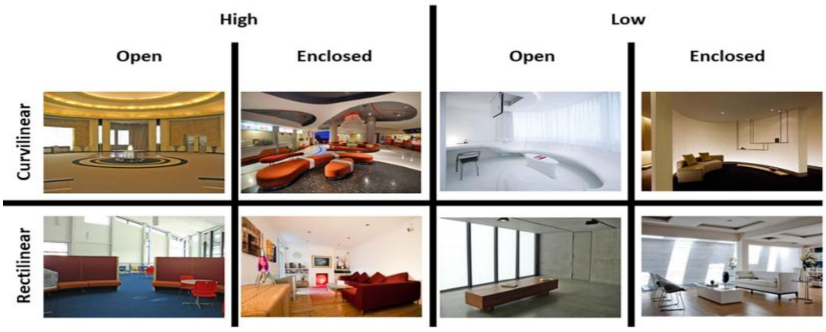

Figure 4 : Brain Scan Study: Contrasting Approach-Avoidance Responses to Curvilinear and Rectilinear Interiors, reference: (vartanian, 2013)

Hearing

Hearing interprets sounds in spaces, creating an experience different from sight. Acoustics contribute character and dynamism. Silence in architecture leads to unique sensations. Architects plan acoustics but adjustments may happen later. There is a perception that sounds, especially in work settings, are disruptive (Hawkes, 2008) . Sound gives a space personality, defining and connecting you to it (Pallasmaa, 1994). When we hear sounds, our ears transmit them through the auditory canal, making the eardrum vibrate. This vibration passes through the middle ear to the cochlea, where discrimination and enhancement occur. The middle ear is crucial for accurate sound perception. Our sensitivity to sounds ranges from 20 Hz to 20,000 Hz, with the most accurate sensations between 500 Hz and 5,000 Hz (Bluyssen, 2009)'Auditory' includes both hearing and listening, describing the sensory experience of sound and its environmental qualities (Rodaway, 1994). Music organizes sounds, creating rhythm, while noise is loud and unwanted. Silence, the absence of sound, brings constant, gentle freedom in a state without self-thoughts or desires.

Figure 5 : Acoustics and Relaxation, Thermo Vals Spa, reference: (Choudhury, 2016)

Smell

Smells, though not visual, trigger memories and shape our perception of places with just eight molecules. Olfaction, more than a chemical sensation, guides us in life and influences our relationship with spaces (Rodaway, 1994). The nose, filtering air and sensing quality, allows specific pollutants to reach the olfactory system (Bluyssen, 2009; Rawson, 2005). Smell imprints memories of spaces with unique odors influenced by finishes. Cities have distinct smells as identity markers. The olfactory system, with millions of receptors, shapes our perception of air quality, influenced by past experiences. Olfactory adaptation determines odor intensity. Architectural design often focuses on eliminating unpleasant smells (Bluyssen, 2009). Smell in spaces is often overlooked but extremely sensitive, sometimes noticed through sight first. Smells come from various sources, impacting memories, and are interpreted within cultural contexts (J, 1982). Each environment has a unique smell shaped by its function, activities, and materials. Strategic placement of building components allows smells to mingle, involving a subtle transfer of experiences. Specific colors and details can evoke both oral and visual sensations (Pallasmaa, 1994)

Figure 6 : The Art of Scent – New York, USA, reference: (renfro, 2012)

Figure 7 : Thermae Vals Spa by Zumthor: Expressions in Materiality, Reference: (zumthor, 2010)

Touch

Touch is about closeness, while the eye observes from a distance. Light and shadow enhance our senses, especially touch. The skin reads texture, weight, density, and temperature. Human touch directly connects with architecture, emphasizing the importance of the environment's materiality. Our skin senses texture, weight, and temperature, connecting us to the world. Vision confirms this information. Light and color affect our feelings through their temperatures on the skin. Losing materiality reduces tactile experiences. Touch is our most direct sense, telling us about the things around us—their weight, texture, and temperature. Our skin acts as a bridge between our body and surroundings, letting us explore and interact with the tactile world (Tuan, 1993).Good architecture lets our eyes "touch" shapes and surfaces, connecting the tactile sense to time and tradition. We often forget the touch aspect, starting with the door handle—the building's handshake. Inside, the feel of materials like wood, marble, steel, and brick contributes to the tactile experience (Pallasmaa, 2005).

Taste

Taste buds on the tongue detect sweet, salty, sour, and bitter flavors, relaying information to the brain. Food flavors influence nerve endings and guide the brain's response. In a gallery, liquids with different tastes and colors lead visitors closer to the sea. Colors like red, brown, and yellow/orange evoke specific flavors. Taste is a subjective and culturally learned process, challenging for observers to comprehend (Simmel, 1994). Unique flavors of exotic foods create a sense of "otherness." (Degen, 2008). Restaurants have become "incubators of innovation," nurturing symbolic culture on various levels. Cafe culture is a good example. In architecture, taste is an abstract concept tied to other senses. While we do not literally taste materials like stone, a specific scent or texture can enhance the experience to the point of affecting our sense of taste. Tactile and taste experiences are closely connected. Taste is influenced by both the nose and tongue, and the eyes and tongue also team up. Certain colors and details have been found to create oral sensations. (Choudhury, 2016) The mouth cavity is an ancient source of architectural space. Exploring taste's various aspects and multi-sensory fusions enhances the architectural experience. Emphasizing taste in architecture brings the body into intimate contact with the world (Perliss, 2006).

Human perception and spatial layout- Architecture influences how we navigate space, involving conscious projection of images and registering stimuli (Arnheim, 1998). Over time, intangible presences, lacking permanence, shape situations (Böhme, 2001).

Perception- Our bodies are central to sensing the world. Our senses, linked to our body's structure, shape how we see and remember places, helping us understand architecture and space. (Pallasmaa, 2005). Perception is a dynamic dance between us and our surroundings, shaping the space that connects us to the world. It involves recognizing things based on a small part of our experience. (Matteis, 2019).

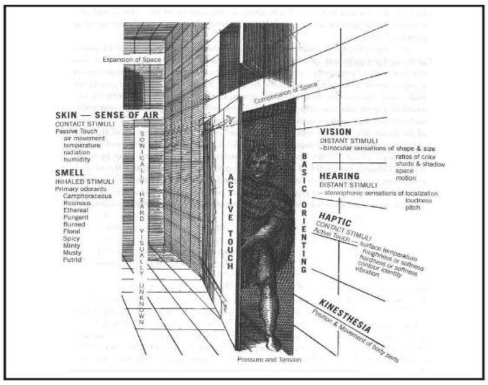

Figure 8 : Ranges of senses, reference: (vodvarka, 2004)

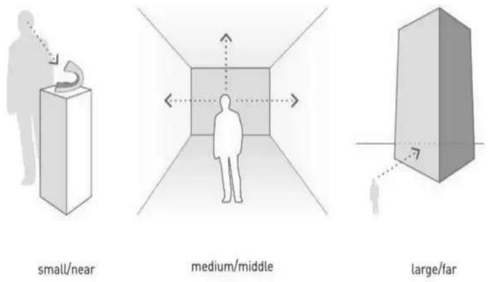

Figure 9 : Spatial perception and architecture, reference: (LTD, 2017)

Spatial layout- A confined or unoccupied location or space (J. A. Simpson, 1989). Space is the gap that partly separates humans from their surroundings and enables them to execute their activities there. (Hasol, 2010)

Space- The realm where everything exists and moves. The distance or separation between two or more objects.

Volume or area- Space is the expression of how the environment is perceived by the subject in a particular moment. (Matteis, 2019)The emotional response to space involves a bidirectional interplay of motion and emotion. Feeling space is shaped by design, influenced by individuals' backgrounds and mood. Lighting, affecting perceptions and moods, interacts dynamically with color, texture, and emotional atmosphere (Meisenheimer, 2004; Jay, 1993).Our bodies and senses anchor us in the world, shaping our perception of space. Senses are vital for interacting with the environment. Morton Heilig's multisensory approach in cinema raises questions about overlooked aspects in architecture (Rodaway, 1994).

Elements of spatial perception- Spatial perception factors, identified by Ching and Zevi as void, boundary, movement, time, and light, play a crucial role in shaping individuals' perception and experience of space (Zevi, 1993).

Void and Boundary- When void and boundary come together, space is created, and their isolation is insufficient for defining space (Ching, 1979) (Zevi, 1993). Voids encompass values like depth, length, motion, and light, while the boundary consists of both objective and subjective components (Kuban, 1990). Spaces involve objective elements like walls and subjective components such as light, music, and temperature, influencing human experiences (Ataç, 1990). The interconnected elements of boundary and void define both interior and exterior spaces, reflecting the interdependence between them (Zevi, 1993). The distinction between interior and exterior spaces is subjective and dependent on individual perceptions (Norberg-schulz, 1988). Bozkurt emphasizes the need for open living environments with unrestricted access between interior and exterior spaces (Merleau-Ponty, 1962). The division between spaces, both physically and perceptually, is influenced by elements like floor texture (Rasmussen, 1959).

Movement and time- Time and motion, including speed, are crucial aspects in the perception of space.(Ching, 1979) (Zevi, 1993). Movement through space is like a perceptual thread linking spaces together, experienced in relation to where one has been and where one anticipates going. A person "lives" in a space by moving through it, reshaping it in their mind, and recording what they see and feel by fusing fresh senses with memories and experiences (Ching, 1979). Movement speed influences how a person perceives space, with slower speeds increasing environmental awareness (Miller, 2008). Time is conceptualized in space as a metaphor, affecting how we comprehend space and the activities within it. Time is complex, categorized into intervals between perceptions and intervals spent in the void The perception of space changes with the time spent, with longer durations leading to diverging perceptions and a heightened memory of environmental characteristics (Ching, 1979) (Zevi, 1993).

Light- Light shapes space by revealing its elements, making them visible and aiding recognition (Zumthor, Atmospheres: Architectural Environments, Surrounding Objects, 2006).Three key components—void, boundary, time-motion, and light—contribute to space construction (Ching, 1979) (Zevi, 1993). Poincare distinguishes physical and experiential space, with the latter involving sensory. Physical space is objective and three-dimensional (Hoogstad, 1990). Norberg-Schulz categorizes spaces as abstract, existential, pragmatic, perceptual, and cognitive (Norberg-schulz, 1988).

Memory

Memory holds a significant role in architecture, representing time past and serving as the present's access to the past. Traditionally, memory was seen as recalling or spontaneously resurfacing past images impressed in the mind (Sebastiano, 2001). It is a dynamic interplay with the senses, evoking emotions and constructing mental places. Memory, perception, and imagination interact constantly, influencing our experience of built forms (Pallasmaa, 2005). In architecture, memory adds a vital dimension, coloring our reality with past experiences and projecting emotions onto spaces. Sensory-guided architecture taps into associative memories, enriching our experience of the world (Zumthor, 1998).

Body and memory

Our bodies play a big role in how we see and understand the world around us. Our senses, like touch and sight, act as a bridge between us and our environment. Our body is like the center of our world, and we experience everything through it. We have close-up senses, like smell and touch, and faraway senses, like hearing and sight. Our body, with its ability to move and remember, helps us create a sort of map of the places we go. Technology also helps us explore and feel connected to a world beyond our body. (Rodaway, 1994) . The way things feel, like the texture of surfaces, helps us know and remember different places. Our lives mostly happen in towns and cities, and the unique characteristics of urban spaces help us feel a sense of belonging and familiarity in this world (Mathews, 2003).

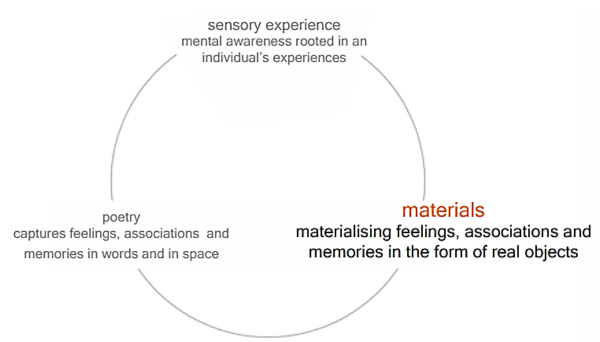

Figure 10 : The three factors influencing memories of a built environment, reference: (Mathews, 2003)

Results and discussions

The survey conducted among DCRUST students and professors reveals a notable interest and appreciation for building designs that engage multiple senses, emphasizing a strong preference for visually appealing spaces. Most respondents believe in the practicality of incorporating sensory engagement into everyday architectural design, reflecting a shared sentiment regarding the importance of ambiance and personalization in the built environment. The findings underscore the influence of cultural context on design preferences and highlight a nuanced stance on the integration of technology in enhancing sensory experiences. This insight provides valuable considerations for architects and designers catering to the sensory preferences of the DCRUST academic community.

The survey, reflecting responses primarily from individuals aged 18-24, elucidates a considerable interest and awareness regarding multi-sensory engagement in architectural design. Over 80% of the respondents have either visited or heard about places that specifically focus on engaging multiple senses. When considering the importance of sensory aspects in building perception, a significant proportion expressed a preference for visual aesthetics, with 81.4% considering sight as the most crucial sense in building design. Despite this, participants acknowledged the importance of other senses, with 45.7% indicating that each sense is valuable in building perception. Technology aimed at enhancing sensory experiences was generally well-received, with 78.6% expressing positive attitudes (18.6% really like it, 30% like it). Participants overwhelmingly deemed the engagement of senses in everyday places as important, with 84.3% indicating that it matters either significantly or very much. The cultural and historical context was widely recognized as influential in shaping how buildings are designed to engage the senses, with 95.7% acknowledging this impact. Additionally, respondents demonstrated a strong correlation between sensory elements, ambiance, and mood, with 98.6% agreeing that the ambiance of a space influences their mood. In terms of personal preferences, a majority (91.4%) expressed a liking for spaces that allow for personalization, such as adjustable lighting and customizable features. The findings collectively underscore a robust appreciation for diverse sensory experiences in architectural spaces, emphasizing the centrality of visual aesthetics while recognizing the importance of other senses, technology, cultural context, and personalization.

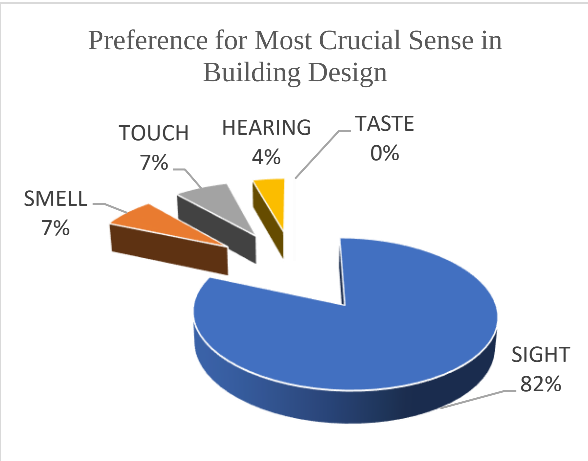

Figure 11 : Preference for Most Crucial Sense in Building Design

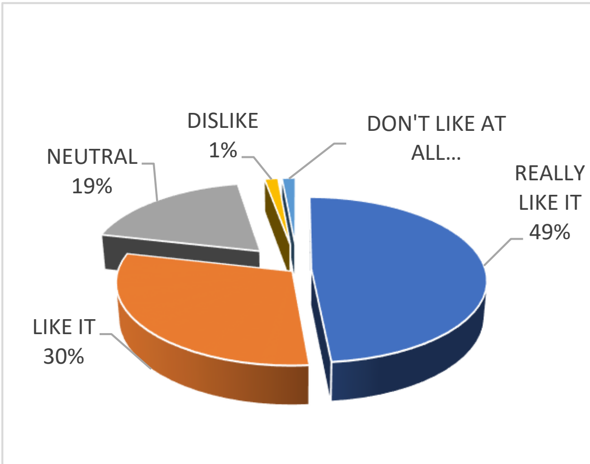

Figure 12 : Thought about technology being used to enhance the sensory experience in buildings

CONCLUSION

The research introduces the idea of multisensory architecture, which is the art of creating spaces that engage not just one, but all our senses. It traces the historical evolution of sensory design, from ancient cultures to contemporary trends, and examines the theoretical frameworks and key concepts that underpin multisensory architecture. It also discusses the role of architects as artists who masterfully blend sensory elements to create meaningful and immersive environments. The research explores the role of each of the five major senses (vision, hearing, smell, touch, and taste) in shaping the perception, emotion, and well-being of users within built environments. It discusses the design strategies and techniques for enhancing sensory experiences, such as visual aesthetics, acoustic design, tactile and material experience, and environmental factors. It also addresses the cultural, contextual, and ethical considerations of sensory design, as well as the challenges and opportunities associated with technological advancements, sustainability practices, and user diversity. The research highlights the importance of multisensory architecture in enriching human experiences and creating spaces that not only meet functional requirements but also elicit emotional connections and foster a sense of place. It emphasizes the need for designing spaces that cater to diverse sensory needs, including those of people with sensory impairments. It also touches upon the psychological and physiological effects of sensory elements, as well as the potential future directions in multisensory architecture that could shape architectural practice and the design of built environments. It also addresses the cultural, contextual, and ethical considerations of sensory design, as well as the challenges and opportunities associated with technological advancements, sustainability practices, and user diversity. The research examines how human perception and spatial layout interact to influence sensory experiences. It explains how spatial organization, circulation pathways, and spatial proportions can guide users' movement and interactions, impacting how they engage with the environment. It also highlights the psychological and physiological effects of sensory elements, as well as the potential future directions in multisensory architecture that could shape architectural practice and the design of built environments. The research concludes by emphasizing the importance of multisensory architecture in enriching human experiences and creating spaces that not only meet functional requirements but also elicit emotional connections and foster a sense of place. It emphasizes the need for designing spaces that cater to diverse sensory needs, including those of people with sensory impairments. It also touches upon the implications of sensory architecture on architectural practice, education, and the future of sensory architecture.

CONFLICTS OF INTEREST

No conflicts of interest were declared by the authors.

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Re-evaluating the Public Buildings in the Post-Pandemic Era

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Abstract— The COVID-19 pandemic caused a significant shift in how public building spaces were used. As public health concerns took priority and social distancing measures were enforced, public buildings, historically the quintessential hubs of social interaction, cultural activities, and economic vitality, were abruptly transformed. As a result, the usual design and use of public building spaces must be thoroughly re-evaluated in the post-pandemic period. The issue at hand is how to strike a balance between the fundamental worth of these places as drivers of social, cultural, and economic vitality and the crucial demands of safety, flexibility, and resilience in the face of upcoming public health catastrophes. The aim is to understand how public building spaces should be designed and built to prioritize health and well-being, whilst not sacrificing their sociability. The research begins by looking at the growth of architectural paradigms of public building designs from the pre-pandemic era to the current issues given by the global health crisis. The scope of the research is a post-pandemic reassessment of existing public building spaces, with an emphasis on important design ideas, user experiences, and strategies for future architectural designs. This research examines the vulnerabilities highlighted by the pandemic in current public buildings. It provides new design solutions to overcome these vulnerabilities such as circulation routes, and seating arrangements, to prioritize health and safety features in their designs and spatial layouts to provide a safe spacing and environment to people. For a wider range of research, literature review design strategies by various international organizations such as American Institute of Architects (AIA), Perkins and Will, Model of Architecture Serving Society (MASS) design groups, and case studies of Design District Canteen, London, UK constructed in 2021, Metaverse Work Pod, South Korea constructed in 2022, The office cum factory, Ahmedabad constructed in 2022 and The Olifant Café, Indonesia constructed in 2022. In addition to above, the design strategies for hospital buildings in the post-pandemic era are also discussed to prioritize health and wellbeing that integrates biophilic design, cross ventilation, natural light, indoor air quality, modular construction, hygienic building materials, and other architectural design considerations. The research concludes to create resilient, adaptable, and inclusive public building spaces that can withstand challenges by integrating flexible design principles, modern technologies and architectural guidelines.

Keywords: Covid-19; Vaccination; Confusion matrix; Cancer and diabetes.

INTRODUCTION

The COVID-19 pandemic that occurred between 2019 and 2020 was an unprecedented global health crisis that caused a significant shift in the way we perceive, utilize, and design public building spaces. As public health concerns took priority and social distancing measures were enforced, public buildings, which have historically been the essential hubs of social interaction, cultural activities, and economic vitality, were abruptly transformed. The pandemic exposed the fragility of our conventional understanding of these public building spaces, leading to a rigorous re-evaluation of such public building spaces in the post-pandemic era. These include public spaces like theaters, museums, libraries, sports arenas open to the public, and hospitals where people can gather and engage in activities (Eltarabily, 2020). The disruption of these fundamental functions of public building spaces led to feelings of isolation, anxiety, and a longing for the pre-pandemic sense of community and togetherness at the time of pandemics; Emergency hospitals may use public architectural spaces such as conference centers and stadiums. According to Hassanzadeh-Rad (2020), altering the pre-existing structures was the quickest and most practical alternative. Despite their apparent antiquated appearance, these temporary hospitals represent the best choice available. Everywhere the same circumstances prevailed.

The COVID-19 pandemic has brought many challenges within global health infrastructures, as reported by several researchers. The documented lack of availability of medical supplies, especially ventilators and personal protective equipment (PPE), has exacerbated critical shortages in certain locations (Smith et al., 2020; Jones & Brown, 2019). Financial strain is evident, with healthcare systems and public building spaces grappling with increased costs associated with procuring additional resources and managing the crisis (Garcia & Smith, 2021; Patel et al., 2019). These multifaceted issues underscore the intricate nature of the global response to the COVID-19 pandemic and emphasize the need for comprehensive strategies to strengthen health infrastructures and also public building spaces. Hence, architects may concentrate on designing rooms that are resilient to pandemics and rediscovering social and recreational functions (Samuelsson, 2020). After this pandemic, new standards for defining public building areas and planning in terms of distances and densities or the presence of public health hazards may become required. This shift in perception has significant implications, as it influences not only the willingness of individuals to use public building spaces but also the public's support for these spaces (Wolch et al., 2022). Thus, understanding and addressing these shifting perceptions are paramount in the process of rethinking public building spaces in the post-pandemic era.

LITERATURE REVIEW

Changing Perceptions of Public Spaces: From Comfort to Concern

The COVID-19 pandemic precipitated a seismic shift in public space utilization (Smith et al., 2021). To curb the spread of the virus, governments around the world imposed strict lockdowns and introduced social distancing measures. These measures led to a dramatic decline in patronage of public buildings and spaces. Parks, museums, and libraries, once bustling with visitors, became entirely deserted. As Yan's study (2021) on the psychology of public space during the pandemic demonstrates, the fear of contagion and uncertainty led people to retreat from communal spaces. Social distancing guidelines altered the accessibility and capacity of public spaces, resulting in a transformation from vibrant community hubs to underutilized and constrained areas (Bodin & Wijkström, 2020). The immediate reduction in public space engagement required a swift adaptation to changing usage patterns. This swift shift in perception has significant implications, as it influences not only the willingness of individuals to use public spaces but also the public's support for these spaces (Wolch et al., 2022). Thus, understanding and addressing these shifting perceptions are paramount in the process of rethinking public building spaces in the post-pandemic era.

Kim and Susser's study (2021) on the psychosocial impact of the COVID-19 pandemic on park use and attitudes illustrates how the restrictions affected people's mental health and well-being. The disruption of these fundamental functions of public spaces led to feelings of isolation, anxiety, and a longing for the pre-pandemic sense of community and togetherness. As the pandemic unfolded, the decline in patronage, coupled with the need to implement stringent emphasized the economic impact of COVID-19 on parks and recreation, highlighting the challenges public buildings faced in sustaining their operations during the pandemic. Reduced attendance, restrictions on gatherings, and additional expenses related to safety measures resulted in revenue losses and increased operational costs. The need for public buildings to reimagine their financial models and explore innovative strategies for economic resilience has never been more apparent. Financial sustainability is integral to the long-term viability of these spaces and their ability to continue serving their communities (Navaratnam et al., 2022).

Contribution of International Organization in Creating Resilient Environments for public buildings

Spatial Strategies for Restaurants by Model of Architecture Serving Society (MASS)

MASS Design Group is a team of over 200 professionals from 20 countries, including architects, engineers, builders, landscape architects, furniture designers, makers, writers, filmmakers, and researchers. Despite the lack of any formal design guidelines, MASS has developed specific strategies that can aid restaurants in their response to COVID-19.

Protocols for food safety and sanitation as per spatial challenges.

They will serve as a model for other businesses working to re-open if they follow the following clinical protocols:

- One possible solution to limit the spread of droplets is by using sequence spaces.
- Minimize the spread of infection through contact with contaminated surfaces.
- "Preventing the spread of airborne infections."
- Consider reconsidering the design and functionality of toilets and handwashing stations to improve sanitation and hygiene.

Take back the restaurant's place in the community.

To preserve our public areas, local governments and legislators should quickly alter the zoning code to remove obstacles to eateries' expansion of outdoor dining into parking lots and the public right-of-way, as well as to provide more room for bicyclists and walkers.

Finally, MASS adds 4 additional recommendations for optimum efficiency:

- Consider implementing a ventilation strategy that is easy to comprehend and demonstrates environmental safety. The ventilation system must be easily seen and recognized for all building occupants to breathe in a safe and healthy atmosphere.
- A feature that may be used is safe, separate storage for staff valuables, prescription medications, and gadgets. This provides them with a secure location to store their belongings while they're at work.The new protocols, which include PPE, temperature checks, handwashing stations, ordering procedures, and social distancing guidelines, will be visible to the public and easily obtainable through documentation.
- Highly visible wall and floor markings, as well as movement-controlling and -guiding signs.

Space	Prev	New MAX
Workstations	98	50
Private Offices	2	2
Enclosed Mtg	67	24
Open Collab	32	9
Total	199	85

Figure 4 : Physical distance analysis- Floor Plan

Guideline for Office Buildings by Perkins and Will

As the COVID-19 pandemic has reshaped the way we work, Perkins and Will have devised a comprehensive set of strategies to guide offices through a phased and multifaceted approach to safely resume operations. In response to the unprecedented challenges posed by the pandemic, Perkins and Will's guidelines focus on a well-thought-out phased return to the office.

Key Strategies:

Planning a Phased Return Calculation of the maximum number of workstations, private offices, and collaborative seats that may be utilized concurrently based on a 6-foot distance. defining a floor's maximum capacity to avoid packing communal areas.

Commute and Building Access:

- Acknowledgment of commuting as a personal choice, with a focus on educating employees about options and providing flexibility.
- Anticipation of an increase in biking to work as an alternative to mass transit.
- Enhanced safety and efficiency measures at building entries, elevators, stairs, and escalators.

Physical Distance Analysis:

- Concentrated analysis on stationary positions, including workspace assignments, enclosed rooms, and areas of standing congestion.
- Utilization of visual guidance for distancing on stationary objects, emphasizing personal diligence.
- Creation of a systematic floor plan analysis using scaling and measuring tools, including the establishment of a 6 ft. radius circle guide.
- Maximum room occupancy indications on enclosed room doors based on physical distance guidelines.

These strategies given by Perkins and Will (2020) highlight the importance of a phased and well-informed approach in planning for a safe return to office spaces. Perkins and Will's strategies, grounded in public health guidance, serve as a valuable resource for employers seeking a resilient and health-conscious transition, ensuring the well-being of employees in the post-pandemic work landscape.

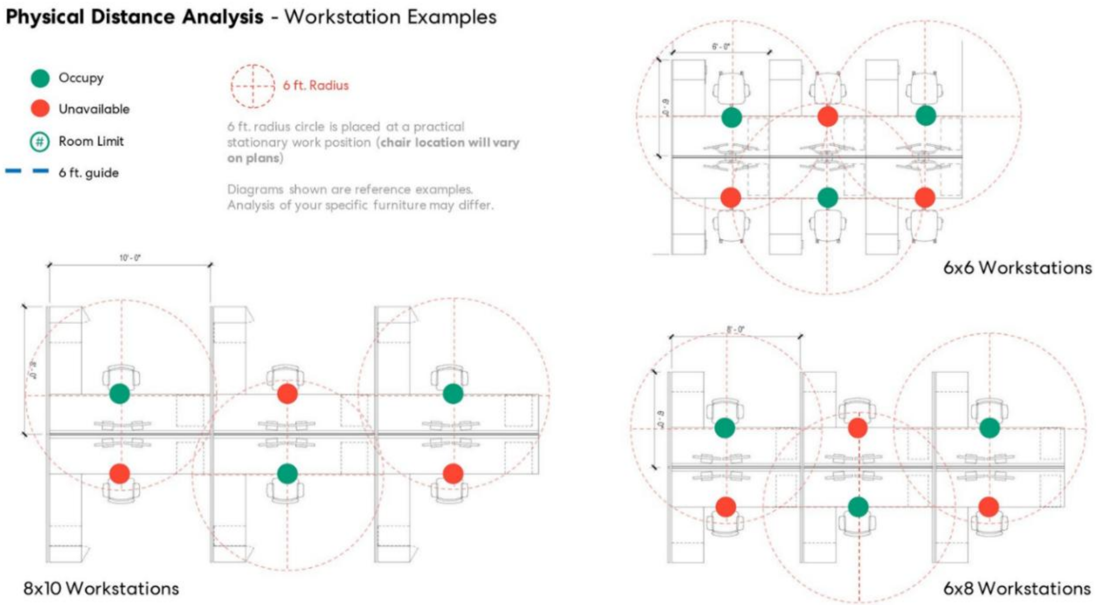


Figure 2 : Physical Distance Analysis -Workstation Design Strategies for School Buildings by American Institute of Architects AIA

To lessen the danger of COVID-19 in schools, the American Institute of Architects (AIA) has published guidelines, diagrams, and 3D design models (YEAR). The AIA's "Reopening America: Strategies for Safer Buildings" campaign includes the design criteria to help education officials reopen schools during the epidemic.

An investigation and risk assessment of Kindergarten–12 schools was conducted by the AIA team, which includes architects, public health specialists, engineers, and facility managers. The decision about the reopening of Kindergarten–12 schools this autumn is still up in the air. Developed ways to reduce the danger of COVID-19 transmission were presented in the study's conclusion. Furthermore, the study "explains the various aspects that must be taken into account when schools reopen and offers fundamental building blocks that can be modified on an individual basis when collaborating with design teams to guarantee that the requirements of specific educational facilities are satisfied when modifying buildings for COVID-19."

Double classroom (1,600 sq. ft.)

The numbered strategies below reference the ALA Re-occupancy Assessment Tool framework.

It is advised to:

- Map the floor surface to determine regions for circulation and/or furniture placement.
- Install retrofit locking casters to restrict furniture mobility to facilitate physical distance.
- Provide students with access to cleansers and throwaway towels so they may tidy their desks before and after using them.
- Provide programming spaces outside
- Utilize natural light sources wherever possible
- Use moveable windows to bring in outside air if at all practicable
- Workstations should be arranged so they face the same way

General Architectural design strategies for hospital buildings (Makram & El-Ashmawy, 2022) Corridor- The 1.80m comfortable distance may affect other walking-related activities and the required width of the corridor. The minimum width of single corridors has been changed to 4.80 meters, and the minimum width of double corridors to 9.60 meters, to fulfill the requirement for appropriate walking lengths during pandemic walks.

Entrance- The width of the entry has been changed to a minimum of 5.40 meters, with a minimum width of 2.40 meters for each opening, to ensure a comfortable distance.

Lift and Lift Lobby- This means that the 1.80 m comfortable pandemic distance may be accommodated by adjusting the regular width of the pandemic elevator. For example, an elevator that accommodates five people has to be at least six meters by six meters in size. The minimum dimensions for a nine-user elevator are one hundred and eighty meters for the opening width and seventy meters for the area.

Sitting- There has to be 1.80 meters of open space between customers for the seats to become alternate (not close together).

Waiting Room- If there are to be two circulations, there needs to be a minimum of 6.60 meters between seats to allow people to move around and sit apart comfortably.

Lobby- The vestibule serves as a "transition space" between the terrace and the lobby, controlling movement, ventilation, and pandemic hygiene. A vestibule that is large enough is required for an automated system to separate the entry and departure and reduce the possibility of people contacting the aircraft.

Unit-Stacking- A new social area with open and green characteristics may be formed on the balcony by building utilizing the step-back strategy. This area may still be controlled to produce social activities that can take place between apartments above, below, or sideways, converting the balcony into a private-public space.

Balcony- The balcony's initial use during the pandemic has changed, and it is now a location where residents may improve their physical and emotional health. Since the balcony is a private location off-limits to the general public, there is a lot of room to grow the current open space system there.

Terrace- The best place for the elevator lobby's green space to preserve the required lighting, maximize available size, and facilitate indoor-outdoor movement is along the side of the entry area.

Window-The first layer is a glass window with views and lights. In the second tier, greenery is created with a planter box filled with plants. A third-layer resident's privacy is preserved with a flexible window (folding or pivoting) using a lattice design that optimizes ventilation, sunlight, and views.

CASE STUDY

Olifant Café (Indonesia 2020) Makram & El-Ashmawy, 2022

Located at 16 West Pleburan Street, Pleburan, Semarang City, Indonesia, is this café, which was constructed in 2020. It has two levels' worth of indoor and outdoor dining spaces.

Architectural Innovation during Pandemic

Circulation Scenario- This cafe uses "on-table service," which allows customers to place orders and be served by waiters at their tables. To reduce physical contact and maintain physical distance between waiters and customers, the waiter presents the menu to the dining table complete with cutlery by operating procedure. The red arrow depicts the movement of customers.

Temperature Check & Washing Faucet in Lobby- The foyer of Olifant is situated near the café's entrance. A temperature check was done at this location.. Thus, the café cannot let a customer in if they have a fever or a body temperature higher than 37°C.

Physical Distance Layout - The café Olifant uses an approach where a table with four seats is limited to two persons only by placing a (X) mark on the chair to create physical distance between the table and chairs. Following the health protocol standards, there must be a minimum of two meters between each table.

Cafe Service Innovation during Pandemic- To reduce contact during a pandemic, the use of barcode menus on tables has become an innovation in health standards. The cafe's bill can be paid in cash using actual currency or electronically by scanning the GPN barcode at the cashier area.

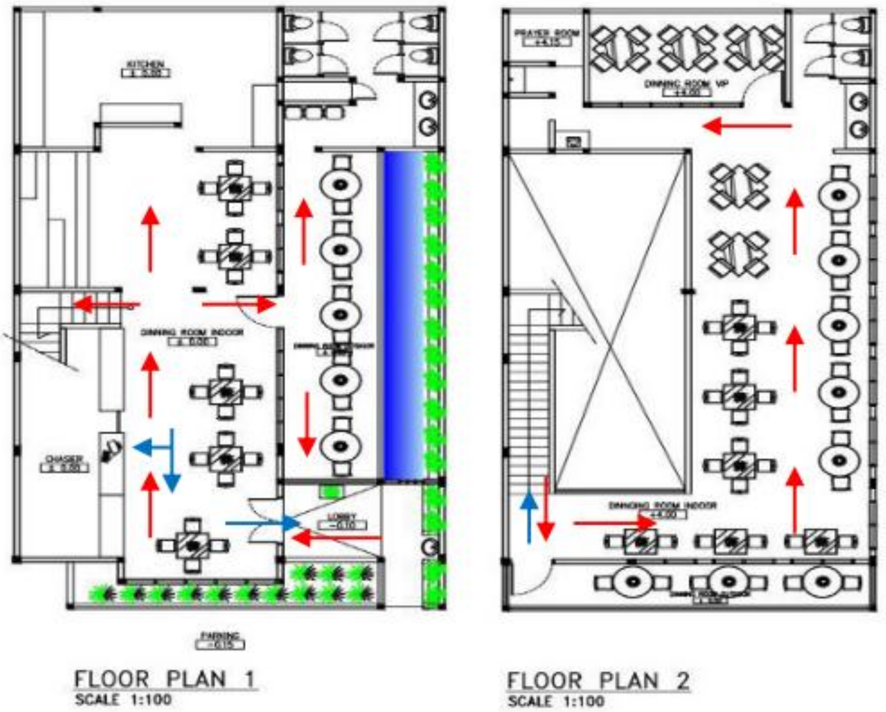


Figure 5 : Floor Plan Showing Circulation

Metaverse Work pod / Design Studio BYO

Constructed in 2022, the 1587 ft^2 design studio, designed by Architects Lee Bong Sik of Design Studio BYO, stands in Jung-gu, South Korea. An effective workplace that is more pleasant and allows for more concentration on work than at home is a cause for concern.

Architectural Innovations

1. Each individual was to have a room that would serve as a location for space control utilizing IOT (Internet of Things) and equipment that might improve productivity at work. These rooms would be easily accessible and utilized for 24 hours a day, without authorization.
2. The primary goals of the project are to protect individual privacy, offer a conducive and concentrated workspace, and set up open meeting rooms and secret rest areas to encourage employees to visit the workplace

"SOMAPOD" means a small device that can be freely accessed and accessed at any time. For extended periods, the most crucial elements for working in a single-person workspace such as "SOMAPOD" are ventilation systems, lighting, and noise levels.

- To reduce noise, each area has two levels of ceiling and two layers of walls.
- In addition, each room has ventilation and air supply air conditioning capabilities, and an illumination control system that the user may directly control was implemented to change the hue and brightness of the light they prefer.

Many shared office spaces have plants placed in areas with open views. These plants help to create a comfortable and relaxed environment, allowing people to work for extended periods. Whether it's for the visual appeal or the connection to nature, having plants around can help to improve the overall atmosphere of the office.

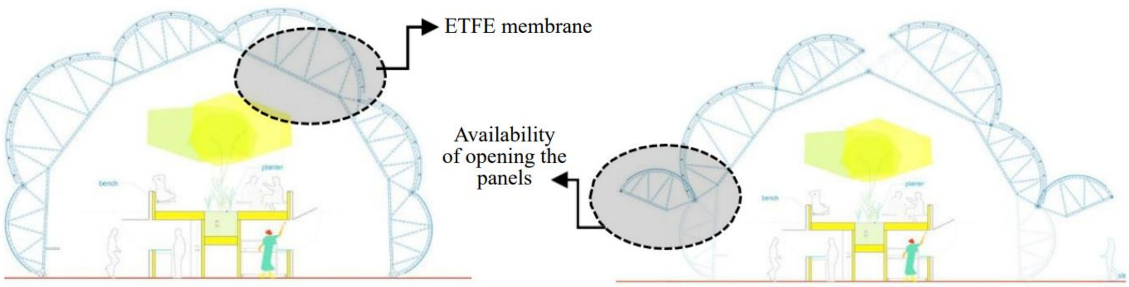


Figure 6 : Concept Diagram

The Greenwich Design District canteen (London ,2021) (Gokhale & Ogale, 2023)

Situated in the Greenwich Peninsula of London, United Kingdom, lies the Design District Canteen. With a building size of 495 square meters, the overall floor area measures 660 square meters. 2019–2021 was the building phase. Before the COVID-19 pandemic, the Greenwich Design District was constructed at Greenwich Peninsula, London, United Kingdom, to provide as a permanent home for the creative industries. With 16 free-standing buildings grouped around five courtyards and occupying 14,000 square meters, the facility offers a variety of office layouts in addition to flexible desk space, workshops, and ateliers.

- To prioritize safety and promote safe interactions, the case study highlights the need to create a well-ventilated, segregated environment with infection control procedures and clear circulation plans.
- It is possible that the Greenwich Design District's architecture had elements that promoted a secure and hygienic atmosphere before the COVID-19 outbreak.
- The notion of constructing a closed contact space with an outer layer of ethylene tetrafluoroethylene (ETFE) membrane is highlighted in the concept. Greenwich Design District served as an example of this idea.
- Transparency: Abundant natural light for inviting spaces.
- Lightweight Design: Enables flexible and innovative structures.
- Durability: Maintains integrity in various weather conditions.
- Ventilation: Facilitates airflow, contributing to healthier indoor environments.
- The primary interaction section of the C4 building, which functions as the market space, may be opened thanks to this design, which encourages air circulation.
- By increasing the intake of fresh air, this feature lowers the concentration of airborne particles and may reduce the danger of transmission.
- Opening the panels is in line with guidelines for establishing secure interior spaces in the event of a pandemic.
- Furthermore, the district's well-defined circulation patterns probably intend to discourage congestion and make physical barriers easier to implement. These arrangements aid in controlling the movement of individuals and guarantee that interactions take place in a safe and regulated way.

The Greenwich Design District's original layout most likely included elements that addressed infection control and safe interactions in addition to placing a high priority on safety. The district's structures functioned effectively during the pandemic, demonstrating that they were equipped to handle the difficulties brought on by the COVID-19 virus.

The office-cum factory (Ahmedabad,2021)

The office-cum-factory of Varnika Components, a capacitor production company in Ahmedabad, underwent renovations in January 2021. The 1,675-square-metre space is located in an industrial park between Ahmedabad and Gandhinagar. Saumil Patel and Prashant Trivedi, the architects behind Squelette Design did the renovation. The name "Squelette" means skeleton and the duo believes in designing the core or skeleton of the building beautifully and functionally, enhancing the space's aesthetics and elegance both inside and out.

Concept- The architects visualized the design to expose the architecture, interiors, and decorations to create an abstract archetype of space. Simple forms were used to create a clear, critical image, with interlocking cubes forming better space planning and elevation to internal space

Architectural innovations in post-pandemic era

Use of Kota Stone and Stucco on Walls: Kota stone's use to lower temperatures in the office area and stucco on walls not only enhances aesthetics but also supports hygiene. These materials may contribute to easier cleaning and maintenance, addressing cleanliness concerns that have become paramount in the post-pandemic context.

Creation of a Cooling Environment in the Reception Area: The creation of a hollow space within the exposed RCC walls to generate a cooling environment is a practical response to climatic considerations. This feature could enhance comfort for individuals entering the space, especially in hot climates. Improved thermal comfort aligns with the focus on creating healthier indoor environments post-pandemic.

Discreetly Concealed Upper-Floor Circulation Passage: Concealing the upper-floor circulation passage with a brick Jali is likely to contribute to better spatial organization and reduced congestion. This approach aligns with the need for efficient circulation and spatial planning to maintain physical distancing in the post-pandemic workplace.

Incorporation of Informal and Separated Spaces in the M.D.'s Office: The M.D.'s office design with an informal approach and visually integrated yet functionally separated spaces reflect a nuanced understanding of contemporary work dynamics. In the post-pandemic era, flexible and adaptable spaces that allow for different work styles, including remote work, are highly valued.

Incorporation of Plants for Improved Ambiance: Adding plants to the interiors contributes to improved indoor air quality and a refreshing ambiance. Such features are increasingly recognized for their positive impact on occupant well-being, which is a key consideration in the post-pandemic era.

Mount Sinai Hospital (New York,2020)

The present Mount Sinai Hospital was redesigned by the MASS design firm to accommodate the COVID-19 case surge that started in mid-March. This case study illustrates the vast steps made by the clinical operations teams, infection control specialists, and Mount Sinai leadership to alter the existing infrastructure, reconsider procedures, and create spatial solutions to deal with the pandemic's problems.

Physical Transformations and Bed Capacity Expansion:

- Conversion of 260 existing patient rooms into negative pressure isolation rooms.
- Construction of a 100-bed step-down care unit in the hospital’s atrium.
- Partnership with Samaritan’s Purse for a temporary 68-bed tent facility.
- Significant changes within adult ICUs, including the construction of walls and doors for fully sealed patient spaces.
- Integration of large HEPA filter units to enhance air quality and exhaust systems.

Challenges and Considerations for Spatial Adaptations:

- Inherited and inflexible infrastructure limitations.
- Difficulty integrating antechambers in adult ICUs due to spatial constraints.
- Spatial challenges in older buildings with larger clinical care teams, compromising spatial distancing.
- Crowded hallways with equipment in pediatric units, affecting workflow efficiency.

Spatial Perception and Spatial Literacy:

- Differences in the way that units identify their danger areas.
- Managing movement between units poses design challenges, especially in vertical healthcare settings.

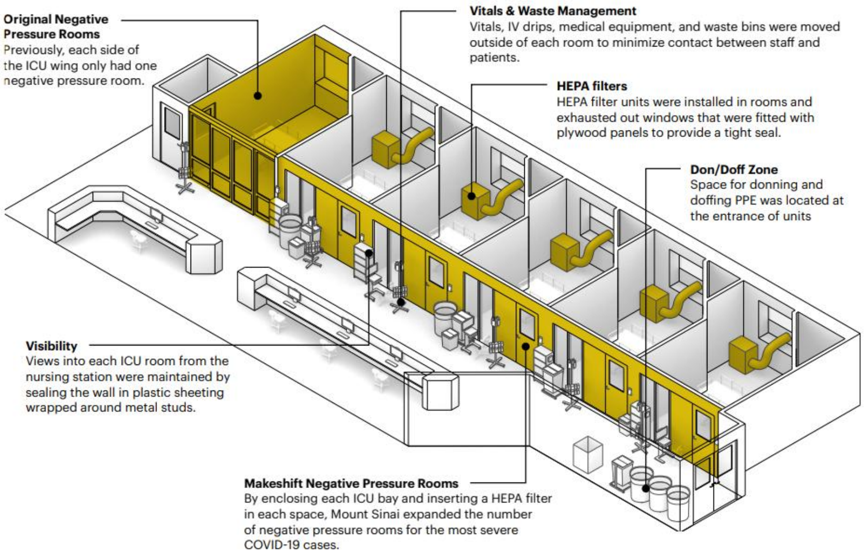


Figure 7 : Diagram if Interventions on the Guggenheim Pavillion

METHOD

Study design - This systematic review was conducted on the available online published studies in high-quality journals related to COVID-19 that were on public buildings.

Search strategy- A thorough extensive literature search was conducted on revaluating the public building space in the post-pandemic era. The following keywords were used such as pandemic, architecture, sustainability, technologies, public building space. Studies that met the eligibility criteria were selected based on the inclusion and exclusion criteria after screening the database for this systematic review.

Research Methodology- The research methodology employed in this study involved a thorough examination of several sources to comprehend the alterations that have occurred in public building areas in the wake of the pandemic. An extensive review of academic journals, trade journals, and trustworthy websites was done to gain a deeper comprehension of the dynamic environment. Rules and regulations were extracted from official eports, and general public views and behaviors were shown by survey data. The primary focus of the study was to categorize data based on significant subjects such as user preferences, health measurements, and architectural design. This data synthesis aims to give architects, urban planners, and legislators practical insights on post-pandemic adaptation through the analysis of real-world case studies.

Experiment and results

Design strategies to create a resilient environment- While the idea of resilient design is not new, the COVID-19 epidemic is making the value of flexibility even more evident. From rearranging one's house for remote work to building up emergency facilities with a temporary shift system, flexible design has proven crucial

Strategies for Social Distancing, Spacing, And Separation- The goal of the building's dispersion and separation strategy is to decrease the number of people utilizing a single building. This helps to recognize the value of social support and constructive interactions with others with proper social distancing.

Design To Enhance Natural Ventilation - Ventilation is used to replace contaminated air, too much heat, and humidity with clean air that satisfies residents' needs for comfort and health.

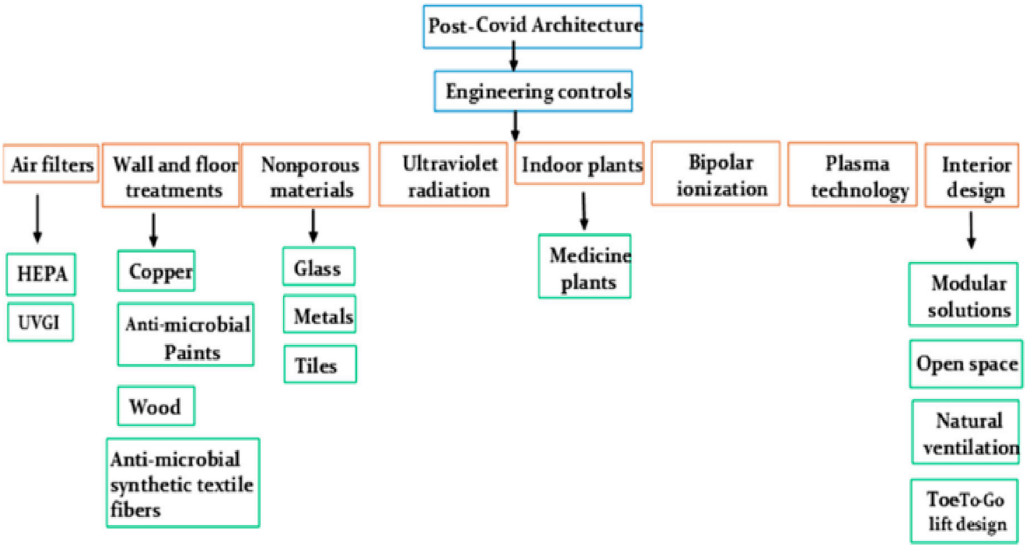
Design To Promote Social Encounters - "Public spaces" are essential in urban environments, as well as in our residences and places of employment. This implies that houses must have sufficient space for social gatherings with loved ones.

Design To Bring Nature Indoors- The appearance of being outdoors during the pandemic may be created by adding natural elements like plants and light, which can have a calming visual impact. "Biophilia" describes the inherent human need to form bonds with the natural world and other living creatures, as well as a preference for the ways that sight and hearing interpret the natural world. In order to support ecologically robust and sustainable natural ecosystems across time, biophilic design should preserve the efficacy and resilience of natural systems (Sharifi, 2022).

Design To Enhance Natural Light- Solar Radiation can operate as a germicide for hazardous germs. Moreover, if diffuse sunlight was consistently let in via windows in homes, microorganisms might be eradicated in five to seven days. Most researches on the relationship between sunshine and health were conducted before the development of antibiotics, but given the current pandemic, there may be an opportunity to explore the potential benefits of these strategies and more effectively integrate them into building design.

Design with construction methods

Building architecture has had to be modified as a result of the COVID-19 pandemic, which has an impact on building construction techniques.



An Increase in Modular Construction- Comparing this construction method to traditional construction, it is quicker, more adaptable, and uses fewer resources. As we witnessed, Wuhan, the heart of the pandemic, constructed two facilities in approximately two weeks using this method: the 1,600-bed Leishenshan Hospital and the 1,000-bed Huoshenshan Medical Facility. This construction's speed and adaptability may have extensive applications beyond the medical field. Rather than creating new components from scratch, modular construction makes use of moveable, flexible parts that may be altered and reused for a variety of applications.

Adaptive Reuse- Repurposing old structures, or adaptive reuse, was another prominent architectural theme during the epidemic. Adaptive reuse is an economic and ecological strategy to build new spaces, particularly in older cities. The Javits Centre in New York has been converted into a 2,900-bed hospital, while the New Orleans Convention Center and the McCormick Centre in Chicago have been converted into 3,000-bed complexes. Moreover, some athletic arenas have been converted into medical establishments (Khalfan, 2022).

Lightweight Structure- Numerous tents have been constructed to function as testing grounds and field hospitals since the pandemic's start. Additional examples include shipping containers transformed into bio leisure areas, rapidly deployable fast recovery units, and transportable modular critical care units. (Khalfan, 2022).

Recommended Solutions for the Post-COVID-19 Existing Building - The construction of the structures we currently have does not effectively inhibit the spread of infectious illnesses. Novel approaches to adaptive reuse must be taken into consideration

In order to resolve this kind of problem. Numerous strategies, including engineering controls, modifying already-existing structures, and improving interior air quality, can be used to accomplish this.

- **Bipolar Ionization-** One of the ionization methods that seems to be most frequently used to stop the virus from spreading through the atmosphere is bipolar ionization. Bipolar ionization devices are inexpensive when it comes to original cost, installation, upkeep, and material costs, which is why many engineers have suggested them. The system's low-pressure drop for the air handling machinery provides an additional benefit.

- There won't be any problems if this system is implemented in any current building, anywhere.
- **UVGI (Upper-Room Ultraviolet Germicidal Irradiation) Technology-** Adding UVGI technology to already-existing structures is an additional direct strategy to stop transmission through the air. This method uses UV light intensity that is safe for humans to lower viral concentrations in huge buildings. UVGI is very suitable for retrofitting older buildings and may offer significant protection at a reasonable cost.
- **Plastic Barrier-** An additional strategy to stop the spread of illness is to divide a sizable open area within a structure with a zipper door and a plastic barrier. This system includes an aerosol generator, pressure gauge, particle counter, and portable HEPA filter. This tactic works better in workplaces, medical facilities, educational institutions, and dormitories.

CONCLUSION

The pandemic has significantly changed how public building space's function, resulting in less foot circulation and the need for strict hygienic regulations. At the forefront of creative design ideas to increase public space safety and flexibility are multifunctionality, better ventilation, and technological integration, as explored by architects and urban planners. Inclusion and equitable access are becoming primary considerations, with an emphasis on serving a variety of user groups, such as those with impairments and people from different socioeconomic backgrounds. This Research paper concludes with to creation of resilient, adaptable, and inclusive public spaces that can withstand the challenges of the future while fostering vibrant and healthy communities by integrating flexible design principles, modern technologies, sustainability measures, architectural guidelines, and an emphasis on social well-being. The optimization of public building spaces involves a holistic approach across design, materials, systems, and technology. In terms of design, measures include expanding gathering spaces, integrating isolation rooms, and ensuring flexibility in building structures, with multiple entries and distinct access zones. Emphasis is placed on incorporating features that facilitate social distancing, such as well-designed entrance areas, waiting zones, and increased outdoor connectivity. Service areas like restrooms, lockers, and clinic access ramps are strategically positioned near main entrances for convenient accessibility. Sustainable design solutions are implemented to enhance environmental responsibility. Material choices prioritize hygiene, incorporating self-cleaning materials and elements that support social distancing practices. Systems improvements entail the adoption of advanced air-conditioning and ventilation systems, along with an increased availability of vertical circulation options like lifts. The integration of treated fresh air further enhances overall ventilation. Technological advancements, including automatic doors, sensors, monitors, and card readers, contribute to touchless access and user-friendly experiences, reducing human contact in public building spaces. These collective measures aim to create resilient, adaptable, and safe environments that prioritize public health, sustainability, and technological innovation within public infrastructure.

CONFLICTS OF INTEREST

No conflicts of interest was declared by the authors.

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Impact of Geometrical Shape of Public Spaces on Perceived Safety of User Group in Case of Bhilai, Chhattisgarh

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Abstract— Safety is considered to be a key factor in determining the quality of public life in public spaces. In cities and towns, public spaces serve as the backdrop for daily activities as well as community life. Safety is determined by a visual and physical connection, physical condition and maintenance, lighting quality, surveillance measures, criminal activities, traffic, and other factors. The impact of the geometrical shape of public space on safety has not been investigated till now. In the case of planned and designed neighborhood townships, the geometrical shape of public spaces can be categorized into three basic forms: Square, Circle, and Triangle. The research aims to analyze the impact of only geometrical shapes on safety in public spaces. Three public spaces of different geometrical shapes identified in Bhilai; Chhattisgarh have been taken for the study. The study is divided into three categories in which data-driven analysis, systematic observation, and subjective judgments are followed extensively. The comparative analysis and results have been achieved through indexing various parameters of safety as per available literature. Through index rating, the result has been achieved as such that the rectangular shape public space is safer than the triangular shape public space followed by the circular shape. The study concludes with recommendations that the geometrical shape of public space influences the safety quotient and needs to be explored further by similar studies on other shapes as well as sizes in other cities.

Keywords: Geometrical shapes, public space, planned, safety

INTRODUCTION

Urban designers, landscape architects, architects, and planners predominantly perceive public space as a tangible expanse, emphasizing the analysis of the correlation between individuals and their environment. The objective of planning and design professionals lies in ensuring the safety of urban public spaces. The safety of urban environments is significantly influenced by the spatial design and geometry of public places. Safety in public spaces has been cited as their top priority. Public space, similar to the concept of place, exists at various levels of comprehension and scales (Relph 1976; Smith and Low 2006). The public domain possesses diverse tangible features, namely roads, squares, and gardens, and includes more extensive entities like residential areas, urban areas, and nations. Furthermore, public space expands to encompass the digital sphere, which comprises the press, the Internet, and even local, national, and international governing bodies. According to the geometric configurations of the designs of public spaces, the classification of public spaces, spatial shapes, and their derived forms can be classified into three fundamental clusters: square, circle, and triangle. (Krier, 1975). The ability of people to use these places effectively, feel secure, and indulge in social interaction with each other is greatly influenced by the layout and design of these areas. Different definitions of public space have been quoted by various authors, with differences in ownership, control, use, and access(Mehta, 2014). According to Jane Jacobs, there is a noticeable increase in the frequency of criminal activity in city public spaces. The way public spaces are designed geometrically reflects a city's philosophy, objectives, and culture. As public spaces continue to develop, the effect of geometrical shapes on safety must be taken into account. The study aims to analyze the impact of the geometrical shape of public space on the perceived safety of user groups. Further investigation is done to study the different types of public spaces concerning geometrical shapes, to assess the safety in public spaces of user groups based on various parameters, and finally to analyze the relationship between the perceived safety of user groups and geometrical shapes of public spaces. The scope of the study is to study and analyze the different parameters related to the perceived safety of user groups in any public space while understanding the perceived safety of the user group through active and passive strategies. The study is limited to understanding the perceived safety concern in only three geometrically shaped areas i.e. rectangle, circle, and triangle. and the study is limited to Bhilai, Chhattisgarh.

LITERATURE REVIEW

Various environmental factors impact the perceived and actual safety of public areas. The design and management of public space have been dominated by rules addressing the increased concerns people have about their safety in the modern day. It is possible to create a sense of safety through specific methods and regulations, but other people contend that excessive policing and securitization can make the area feel noticeably hazardous (Davis 1990). On the other hand, a sense of security can be attained just by having people around and "eyes on the street," where the area acts as its police force. Perceptions, however, are a major factor in determining whether a place appears safe or unsafe.

Based on empirical investigation, an individual's evaluation of their degree of safeguard against illegal activities is subject to various determinants, encompassing the structural conditions and maintenance of a locality, the arrangement of spaces, the types of land utilization, environmental accommodations, and the existence or nonexistence of specific categories of individuals. As per specific scholarly examinations, it was posited that members of the public perceived commercial zones and other non-residential establishments as being more secure. (Perkins et al., 1993). Several additional investigations have revealed that the existence of litter, defacement, intentional destruction, and poorly maintained structures notably affect individuals' impressions regarding security. (Perkins et al., 1992; Skogan & Maxfield, 1981; Hope and Hough 1988). In her treatise on city streets, (Jacobs, 1961) cited shops, pubs, restaurants, and other "third places" as essential elements of security and observation. Creating an urban setting that permits a higher number of individuals to observe their surroundings or guarantees enhanced perceptibility of communal areas is a common strategy employed to enhance safety. (Sarah Isabella Chiodi, 2016). Efforts to promote increased surveillance of public spaces have encompassed the deliberate arrangement of windows and entrances, the revitalization of natural areas, and the elimination of obstructive structures or other significant impediments to the visibility of communal areas. (Cozens & Love, 2015; Sarah Isabella Chiodi, 2016). Jacobs' theory has faced reproval despite its widespread acceptance, predominantly arising from the absence of conclusive evidence establishing a causal relationship between crime decrease or heightened perception of safety and intentional design. (Anderson et al., 2013). Despite these criticisms, correlational research and safety audits have indicated that individuals experience a reduced sense of security in secluded, isolated environments. Conversely, they tend to perceive greater safety in meticulously maintained areas that are populated, and active, and feature open greenery, as well as streets adorned with residences, businesses, dining establishments, and transparent facades. (Cattell et al., 2008). Also, it is concluded by Austin and Sanders (2007), that the ‘eyes on the street’ can be enhanced by the elimination of solid walls as a passive control strategy for safety in public spaces.

Geometrical spatial layout of public space

When creating a classification for public spaces, shapes of spaces and related forms can be grouped into three, based on the layout of their base plans: these groups are based on the square, circle, or triangle (Krier, 1975). Indeed, the size of a public space also connects to the shape properties.

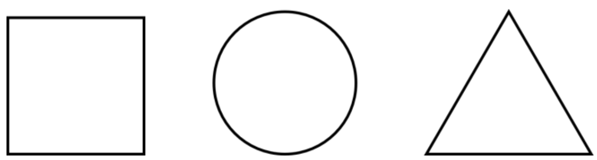


Figure 1 : Geometrical spatial shapes

Spatial layouts and their modulating factors

Method

The shape of public space is influenced by factors. Angling, segmenting, adding, and merging can all alter these spaces. Additionally, elements could overlap or combine, causing distortion (Krier, 1975). These conditions can collectively change the standard shapes of public spaces. The plethora of potential building segments affects the caliber of the space during each modulation phase. Every segment pertains fundamentally to these spatial shapes. This way, this specific typology becomes simpler to grasp and use in practical planning as shown in fig:2.

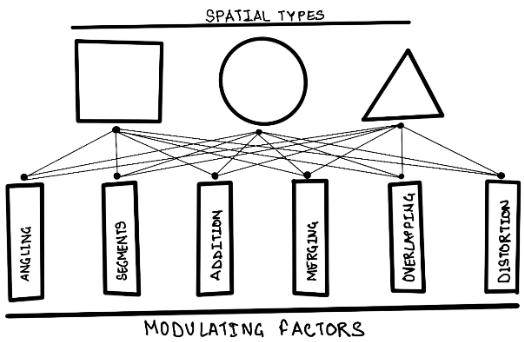


Figure 2 : Spatial types and their modulating factors

METHODOLOGY

The Study is divided into three parts. The first step is to calculate the areas and dimensions of the plans for public spaces. The second part includes site surveying and observations of physical features of public space based on that spaces are rated on certain variables. For the third part, questionnaire surveys have been done to take into account the user's perceptions. Finally, a comparative analysis chart has been made from all the above parts of the studies and scoring criteria to analyze which shape provides more sense of safety.

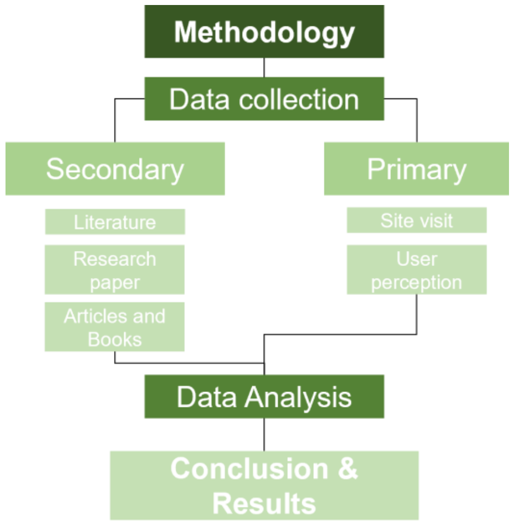


Figure 3 : Methodology

Table 1: Classification of the method for measuring the impact of the geometrical shape of public spaces on the perceived safety of the user group.

Category	Research Methods and Tools	Analytical Units	Data
Data-Driven Analysis	Calculating the Areas and Dimensions on AutoCAD.	Area	Plan
Systematic Observation	Site survey and observation: mapping of the physical features of the space	Space	Subjective perception, Photos and videos, and scoring
Subjective Judgements	Users Subjective rating	Questionaries	Scoring

Data collection

Most of the Indian cities have grown organically and so have the public places are organic in shape. In the case of planned and designed neighborhood townships, the geometrical shape of public spaces can be categorized into three basic forms: Square, Circle, and Triangle. Thus the public spaces that have been selected for study are in geometrical shapes in the planned neighbourhood of Bhilai township, Chhattisgarh. The primary data collection has been done by the author through multiple site visits, mapping of the public spaces, and photography. The user perception survey of the public spaces has also been done with a questionnaire.

Introduction to the city

Bhilai is a city located in the Durg district of the Indian state of Chhattisgarh. It is an industrial town and it was known for its Bhilai steel plant established in 1955. During that time period, the steel plant developed its township for workers with the collaboration of soviet planners. The planned township is in the northwestern part of the Bhilai steel plant. And it is divided into sectors.

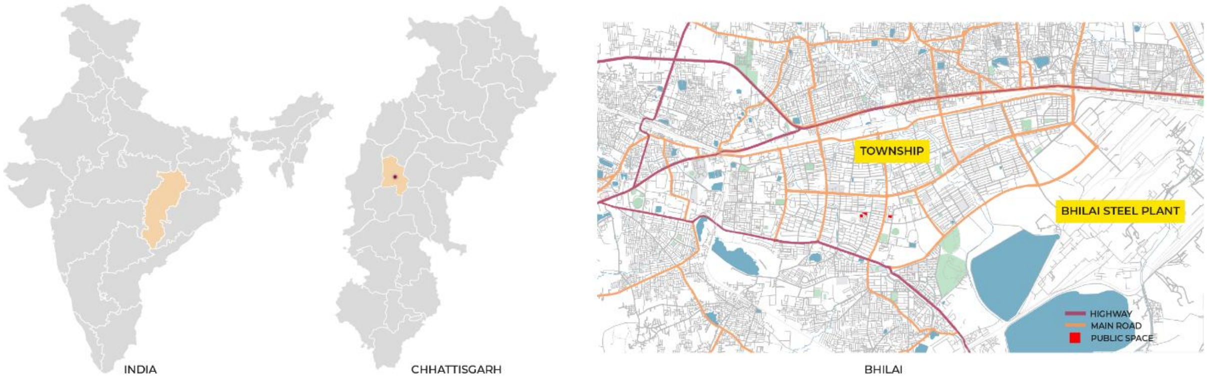


Figure 4 : Location map of Bhilai

Public space 1 rectangular shape (civic center)

The civic center is located in the center of the township. It is known for its civic activities and recreational purposes. This public space is located in the northeast of the civic center area of Bhilai township. The shape of the public space is rectangular surrounded by buildings on three sides and leaving one side open. The use of the building is generally for educational purposes for private coaching classes on the ground floor with residential use on the first floor.

Figure 5 : Mapping of Public Space 1 (Rectangular shape)

Public space 2 circular shape (sector-10)

Sector 10 is located in the western part of the township. The zonal market area of Sector 10 is near to center part of the sector.

It has Markets, Coaching centers, Mechanic shops, etc.

This public space is circular and it has mostly buildings on its edge. Five roads are radiating outwards from the space. This public space is surrounded mostly by coaching centers and shops along with a few mixed uses and residential blocks.

Figure 6 : Mapping of Public Space 2 (Circular shape)

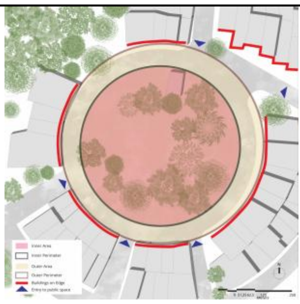
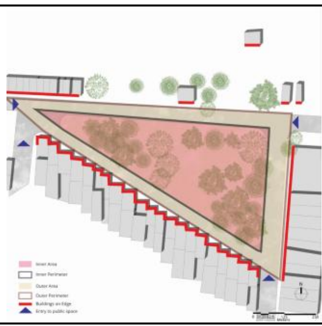
Public space 3 triangular shape (sector-10)

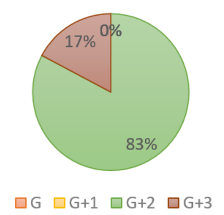
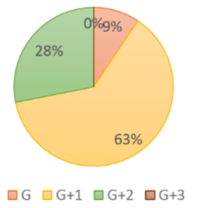
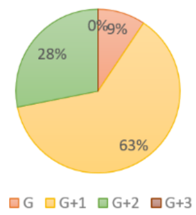
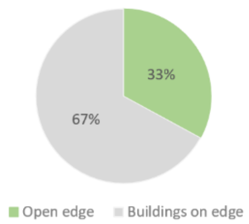
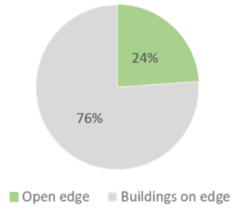
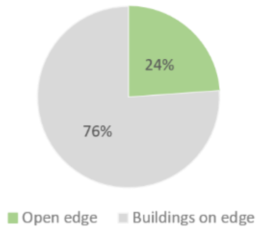
This space is also located in Sector 10. The market area has Mechanic shops, restaurants, coaching centers, etc. This public space is a scalene triangle in shape and it has buildings on two sides on one side it is mostly open land with few petty shops.

Figure 7 : Mapping of Public Space 3 (Triangular shape)

Comparative table

Table 2: Comparative table of public space.

CASE AREA	Public Space 1 Rectangular shape (Civic center)	Public Space 2 Circular shape (Sector-10)	Public Space 3 Triangular shape (Sector-10)
Plan			
Inner Area	1492.60 sqm	2381.24 sqm	2302.14 sqm
Inner Perimeter/circumference	159.67 m	172.98 m	248.26 m
Outer Perimeter/circumference	212.09 m	210.75 m	316.13 m
Outer Area	2738.52 m	3578.47 m	3664.72 m
Buildings on edge (perimeter/Circumference)	142.23 m	160.44 m	181.44 m
Number of Entries	5	5	4
Inner Dimension	49.97X29.87 (LxB)	27.53 (r)	49.19X93.33 (BxH)
Outer Dimension	63.48X43.14 (LxB)	33.75 (r)	62.57X117.14 (BxH)
3-D Block view			
No. of Buildings on the Edge	29	32	47
No. of Windows and Balconies Facing public space	95	50	35

Building height Percentage			
Permeability			

While comparing the three different shaped public spaces taken, the inner area of the circle is larger while the overall area of triangular-shaped spaces is larger. The inner perimeter of the triangle is more with 248.26 m while the rectangle has 159.67m. The permeability in central space is the same between a rectangle and circular public space with 5 no. of entries, while triangular space has 4 entries. The more no. of buildings occupying the perimeter of the spaces is observed in a triangle in the length of 181.44 m. which are 47 in nos. The triangular public space has 53% of buildings on of ground floor level, 41% of buildings are up to the first floor level and 6 buildings are to the second level out of 47. In total, there are 35 windows and balconies in buildings of triangular space facing towards the public space. The inner area of the circular public is the highest with an area of 2381 sq. m. with a circumference of 172.98 m. The circular public space has 76% built edge which covers a length of 160 m, while 24% is unbuilt with 32 buildings on edge. The building height has a major share of 63% as first-floor levels, with second-floor levels up to 28% and 9% with just ground floor level. The no. of balconies and windows on the circular public space facing towards the space 50 in nos. The inner and outer area of triangular space and circular space has negligible differences. The triangular space has inner and outer areas of 2302.14 sq. m. and 3664.72 sq. m. respectively. The triangular public space has a 45% built edge which covers a length of 181.44 m, while 55% is unbuilt with 47 buildings on edge. The building height has a major share of 53% as ground floor levels, with first-floor level up to 41% and 6% with just second-floor level. The no. of balconies and windows on the triangular public space facing towards the space 35 in nos.

The geometrical shape of public space on the safety index

Thorough literature reviews the following variable has been formulated in the following table. The measuring

criteria are of two types one is by researcher observation while another is from the user's perspective. The weighting points have been decided accordingly.

Table 3: Geometrical shape of public space on safety index

Aspect of Public Space	Variables	Weighting	Scoring Criteria
The Geometrical Shape of public space	Determined By Observation		
	Visual and physical connection and openness to	1.0	0=Almost none or very poor 1=Somewhat tentative 2=Moderately well connected 3=Very well connected

on perceived Safety	adjacent streets or spaces		
	Permeability	2.0	3=Highly Permeable 2=Moderately Permeable 1=Slightly Permeable 0=Impermeable
	Perception of Surveillance through built-form	2.0	0=Low Perception 1=Neutral 2=High Perception 3=Very High Perception
	Safety due to the height of buildings	1.0	0=Not at all safety 1=Somewhat unsafe 2=Mostly safe 3=Very safe
	Determined By User Perception		
	Sense of safety	2.0	3=Very much provide a sense of safety 2=Provide some sense of safety 1=Not at all 0=Make me feel Unsafe
	Perceived Safety from the physical condition of the public space	1.0	3=Very much provide a sense of safety 2=Provide some sense of safety 1=Not at all 0=Make me feel Unsafe
	Perceived safety from traffic	1.0	0=Not at all safety 1=Somewhat unsafe 2=Mostly safe 3=Very safe
Total		10	30(maximum)

Determined by observartion

Table 4: Index rating by observation

Study Area	Public Space 1 Rectangular shape (Civic center)	Public Space 2 Circular shape (Sector-10)	Public Space 3 Triangular shape (Sector-10)	Scoring scale (0-3)	Weighting Out of 10
Visual and physical connection and openness to adjacent streets or spaces	2	1	2	0=Almost none or very poor 1=Somewhat tentative 2=Moderately well connected 3=Very well connected	1

Permeability	2	1	3	3=Highly Permeable 2=Moderately Permeable 1=Slightly Permeable 0=Impermeable	2
Perception of Surveillance through built-form	3	2	1	0=Low Perception 1=Neutral 2=High Perception 3=Very High Perception	2
Safety due to the height of buildings	2	1	1	0=Not at all safety 1=Somewhat unsafe 2=Mostly safe 3=Very safe	1

Determined by user perception

The survey has been carried out by the author during a tenure of multiple times on different days. The random sampling was done with 121 users from all three public spaces considered. Out of 121 respondents, 40 users have responded from Public Space 1 Rectangular shape (Civic center), 48 users have responded from Public Space 2 Circular shape (Sector-10) and 33 users have responded from Public Space 3 Triangular shape (Sector-10).

Table 5: Index rating by user perception

Study Area	Public Space 1 Rectangular shape (Civic center)	Public Space 2 Circular shape (Sector-10)	Public Space 3 Triangular shape (Sector-10)	Scoring scale (0-3)	Weighting Out of 10
Sense of safety	2.07	2.13	2.03	3=Very much provide a sense of safety 2=Provide some sense of safety 1=Not at all 0=Make me feel Unsafe	2
Perceived Safety from the physical condition of the public space	1.63	1.94	2.12	0=Not at all 1=Somewhat 2=Mostly 3=Very much	1

Perceived safety from traffic	1.70	1.79	1.73	0=Not at all safety 1=Somewhat unsafe 2=Mostly safe 3=Very safe	1

Determined by user perception

Through the literature review, the parameters have been considered such as Visual and physical connection and openness to adjacent streets or spaces, Permeability, Perception of Surveillance through built-form, and Safety due to the height of buildings, have been considered based on observation while Sense of safety, Perceived Safety from the physical condition of the public space, and Perceived safety from traffic have been considered based on user's perception. The parameters have been compared through indexing in all three public spaces. In that, public space 1 (rectangular shape), has the highest weight which signifies that the perceived safety in rectangular-shaped public spaces is highest in comparison to the circular and triangular-shaped public spaces.

Table 6: Comparative table of indexing

Study Area	Weighting	Public Space 1 Rectangular shape (Civic center)		Public Space 2 Circular shape (Sector-10)		Public Space 3 Triangular shape (Sector-10)	
Visual and physical connection and openness to adjacent streets or spaces	1	2	2	1	1	2	2
Permeability	2	2	4	1	2	3	6
Perception of Surveillance through built-form	2	3	6	2	4	1	2
Safety due to the height of buildings	1	2	2	1	1	1	1
Sense of safety	2	2.07	4.14	2.13	4.26	2.03	4.06
Perceived Safety from the physical condition of the public space	1	1.63	1.63	1.94	1.94	2.12	2.12
Perceived safety from traffic	1	1.70	1.70	1.79	1.79	1.73	1.73
Total	10		21.47		15.99		18.91
Index Rating (out of 100)			72		53		63

CONCLUSION

As per the observation from the index rating diagram it has been concluded that the Public Space 1 rectangular shape, (Civic center) is perceived to be safer than the Public Space 2 Triangular shape, (Market area) followed by Public Space 3, circular shape (Zonal market). The results are established considering observation by the researcher and the user's perceptions.

The results are being concluded by comparing different parameters in which rectangular space has achieved higher permeability and eyes on the street, thus increasing the safety quotient in this space. The height of the building also plays a vital role in the safety concern, in which higher buildings on edges provide more visual permeability due to the presence of more no. of windows, terraces, and openings. The presence of high dead walls in space generally, causes a major safety concern in any public space. In the case of Bhilai, being a planned township, the rectangular public spaces are safer as perceived by the researcher and user's perception.

The results of this research work further need to strengthen keeping other parameters constant in public spaces and can be used to enhance and analyze the safety perspective in public spaces based on different shapes. The above parameters can be considered while designing the public space. The study concludes with recommendations that the geometrical shape of public space influences the safety quotient and needs to be explored further by similar studies on other shapes as well as sizes in other cities. Further research and study in the field of perceived safety in the different geometrically shaped public spaces may get varying results with different weighting of the parameters and contexts. Thus, the resultant is influenced by the geometrical shapes and the site context for the perceived safety in the public spaces.

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Effect of the Pune Metro on it's Influence Zones

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Abstract— Since the establishment of the Pune Metro project, sources have mentioned shifts in the urban paradigm of the city of Pune. Roads and consequently the transportation has been diverted and residents along the proposed metro lines have been impacted in the course of development. Architects and designers have been confronted with several questions regarding development in areas near the metro station following it's construction. Introduction of an elaborate transport line that can cut through city traffic, affordable to the less privileged and convenient for office workers has paved the way for transportation and economic development in Pune. This leads to the question of how an opportunity as impactful as the Pune Metro project can be exercised for the benefit of the city dwellers. Allowance of greater FSI and TDR purchase has permitted the construction of taller, more spacious properties however mere increase in FSI does not solve the problem entirely- there are several legal and configurative constraints that require consideration. Although the cognitive footprint of the metro construction on the inhabitants in Pune is greater, this paper focuses on the impact of this transit oriented development on property rates, rental values and redevelopment prospects. For the purpose of this research, Anand Nagar, Ruby Hall and PCMC metro stations and their respective influence zones have been selected. In order to achieve the proposed aim, interviews have been conducted with consenting architects, developers and brokers working on projects falling under these "influence zones"- influence zones are areas that are contained in a 500 meter radius from the metro station. Additionally, field study and informal discussions with shopkeepers alongside the metro line has helped understand the rental value and redevelopment scenario of the areas closest to the station. The development plan of the Pune Municipal Corporation has been used to compare on site observations and the original proposed land use of the individual areas to confirm the same. The settlement pattern of Pune city is dense and introducing a metro line has added to the narrowing of major roads that run through it. Redevelopment has peaked considerably in efforts to commercialize the streets adjoining the service line. Currently, Pune is experiencing a change in land use and surge in redevelopment in order to provide a better lifestyle to it's residents. This has lead to a rise in the property rates, rental values and general requirement of the public.The station being the main accessible point, the impact is greatest at distances between 200 and 350 meters and perceivers at distances under 500 meters. Hedonic pricing is observed between the ranges of 200 to 350 meters and continues up to 500 meters with respect to the location of the station. This study emphasizes solely on the effect of the metro station, it does not heed to the existing neighbouring amenities.

Keywords: Influence zones; Transit Oriented Development (TOD); Property rates; Redevelopment; Rental values

INTRODUCTION

Transport Oriented Development, also known as TOD is a part of the Indian Government's 'Smart City Mission'- Pune being one of the top choices. Pune as a city is intellectually progressive, economically well off and culturally rich (PMC website, 2023). This makes it one of most desired cities after Mumbai, Delhi and Bangalore by migrants looking for better job opportunities, education and healthcare. Even though Pune is not sought after in comparison to Mumbai or Delhi, the city has been experiencing a spike in it's population in the last ten to twenty years- representing a 2.57% annual change (World Population Review, 2023)

The IT hub of Pune- located in Hinjewadi has a huge influx of employees on a daily basis. Hinjewadi is locatedin the outskirts of the city; in spite of having several housing schemes and allied facilities in the area, some residents prefer living in the city and commuting to work. Not only Hinjewadi, but considerable commute occurs between the extremes of the city for work, education, healthcare as well as entertainment. As an answer to the increasing vehicular traffic on the roads (fig 1), the Pune Metro Project was introduced for improving transport and aiding efficiency for the rubbernecks that travel long distances for a living.

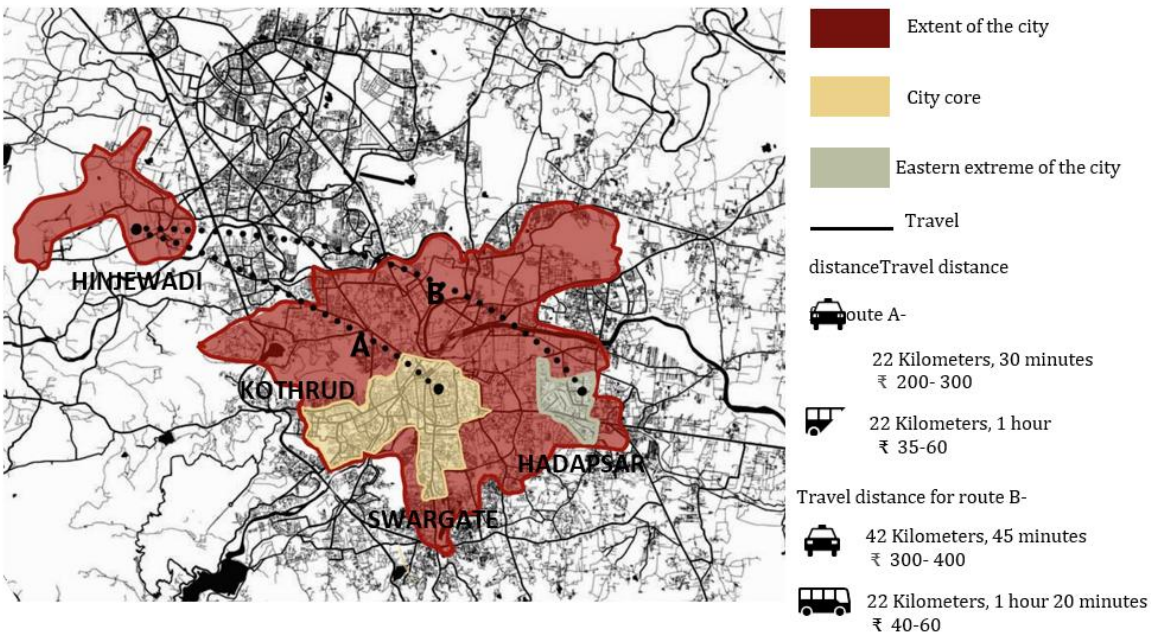


Figure 1 : Image shows location of the IT Hub of Pune- Hinjewadi with respect to the core city and the distance travelled by employees inn a daily basis to commute to their place of work (Pune map sourced from Alamy)

Vehicle	Origin	Destination	Distance	Travel time	Fare
Car	Kothrud	Hinjewadi	22 km	30 minutes	₹ 200-300
	Hadapsar	Hinjewadi	42 km	1 hour	₹ 300-400
Bus	Kothrud	Hinjewadi	22 km	45 minutes	₹ 35-60
	Hadapsar	Hinjewadi	42 km	1 hour 20 minutes	₹ 40-60

METHODOLOGY

Areas of study have been selected under the pretext of "influence zones" pertaining to the metro line with primary emphasis on active and operational stations. The selected areas are located at the cardinal points of thecity. Development plans of these areas have been studied and analysed to understand the proposed land use andexisting building typologies. A comprehensive field study has been performed in the influence zones to assess contemporary land utilisation patterns and redevelopment activities. This field study entails interviews with consenting locals, shop proprietors and pedestrians to understand the change Moreover, systematic interviews have been conducted with willing participants including Architects, Developers and real estate agents to discern shifts in property and rental dynamics.

Semi structured interviews have been conducted with architects, developers and brokers situated/currently working in the selected metro zones, this has provided qualitative and quantitative data about the property rates, redevelopment scenario and rental prices. Development plans of the said regions have been studied and compared with on site observations.

Scope and limitations

To understand the variations in land use, building typologies, property values and rental prices in areas falling under the influences zones of Anand Nagar, Ruby Hall and PCMC metro stations. This study attempts to analyse the reasons behind the rise/hike in property rates and redevelopment scenario in Pune and how they affect the design and construction scenario in Pune. The reason why three stations (located at thecardinal directions) have been selected is to examine and compare the extent of this influence and change in prices. Locations towards the south(Swargate) could not be studied since the construction of the metro line has not yet been completed. The PCMC station despite not falling under the same municipal corporation (PMC) as Anand Nagar and Ruby Hall has been chosen under the pretext of having a completely different set of regulations to begin with. The paper discusses further amendments in the rules and compares it to those of PMC.

LITERATURE REVIEW

Within the field of urban economics, it is anticipated that advancements in transportation infrastructure, such asrail transit systems, as well as changes in accessibility to employment and other opportunities, will impact property values and influence where households and businesses choose to locate. The internal features, external amenities, and accessibility all affect a property's value. The physical attributes of the property are its internal qualities; planning, amenities, facilities, etc. The external features that have an impact on a property's value come from a variables coming from regions surrounding the property. Close at close proximity typically exhibitmore effect than locations that are farther away. The following is the basic hypothesis that explains how property value is impacted by metro accessibility; it relies on fact that due to specific features, a site grows more popular, which raises demand and driving up prices (Wagh and Sonar, 2021).

Over the last six years, with the commencement of the Pune Metro project, inhabitants have observed a substantial transformation in the urban scenery and architectural styles in areas where the initial metro stations were established. Presently, with operational stations and metro lines in place, there is a distinct reversal in the said dynamics. While official reports and articles have outlined the fluctuations in land values and the potential effectson the real estate market, a comprehensive study of the impact of this construction becomes necessary to examine the alterations in land utilisation resulting from redevelopment. Such an investigation can shed light on the shifts in property and rental valuations.

The Pune Metro Project is one of the branches of the Smart City Mission launched by the Government of Indiain 2015 (PMC website, 2023) It was done to improve the transportation system in Pune and connect the West- East and North-South extents of the city which was initially only possible via roads.

The metro line is an overhead service ranging from 17 feet to 21 feet and consists of three lines-

Purple line- 16.60 kilometers long - from PCMC to Swargate- intersects at Civil Court

Aqua line- 14.66 kilometers long- from Vanaz to Ramwadi- intersects at Civil Court

Red Line- 23.33 kilometers long- from Rajiv Gandhi Infotech Park to Civil CourtAll lines either intersect or terminate at Civil Court.

The red line is currently not in use, the purple line terminates at Civil Court and the aqua line terminates at RubyHall. Currently, the usable metro lines have proved to be of great importance to residents who have to travel long distances for work on a daily basis. Consequently, this has given rise to a lot of development around all metro stations. For this purpose, the metro has planned a the train frequencies in order to serve the crowds even during peak hours with minimal wait time and lesser nuisance for booking tickets. (Lokmanya English Desk, 2023)

Development plan of Pune city

As a general observation, one will notice that the major roads- for example, Karve road (fig 1), Paud road (fig 1.1) etc. which run through the entire city have a majority of commercial and mixed used establishments adjoining the road. These are about twenty-four meter wide roads with relatively small sized plots alongside. According to the regulations corroborated prior to the metro construction, the FSI of these plots was calculated on the basis of the width of the main road- which means that the FSI that was originally in use was of 1.1. Therefore the built-up along the major roads did not surpass four storeycity- how it impacts the development of the city, the land values and therefore it's residents; this data will the be compared to the readings and observations collected from the proposed tools and methods after taking the impact of the metro into consideration.

Fig 1.1 . Image showing roadside built along Paud road.(Credit- author, 2023)

Research gap

The Pune metro has been inthe works since 2017, since then only about one research has been conducted (dated 2021) on it's impact on the property rates and rental prices. This paper attempts to focus on the current prospects of Pune's real estate surrounding the metro by virtue of interviews and discussions with experts in the field of construction and real estate. This study is necessary given the fact that the metro before, during and after it's construction has shown varied results in it's impact on the existing urban paradigm of the city. Studies conducted before the completion of the project only suggest anticipated values therefore conducting a study in areas with working metro station is necessary to understand the contemporary footprint of the metro project.

DATA COLLECTION AND ANALYSIS

Field study

With the introduction of the elevated metro, builders are now allowed to build up to an FSI of 4. This has given rise to numerous redevelopment proposals specifically for typologies existing next to the main access road.

Redevelopment inadvertently means better amenities, more carpet area and general lifestyle- this reckons a hikein property rates for former residents and rental prices for shopkeepers. The elevated metro however, has given rise to certain issues such as narrowing of roads, congestion of traffic and insufficient parking space. (fig 1) Roadside shops which originally had reserved parking spaces in the front margins of their property now have to make adjustments elsewhere- these spaces are allotted under flyovers, in nearby open plots or in parking bays offering pay and park services. Places where the metro line is under construction experience heavier traffic thanusual due to the compromised road widths and changes in traffic flow. (fig 1.1)

Figure 3 :. Rerouting to decongest traffic for metro works lead to narrowing of roads. (Credits-Shrinivas Deshpande, 2017) Hindustan Times (2017) Pune Maha Metro's road diversion plan fails to serve purpose)

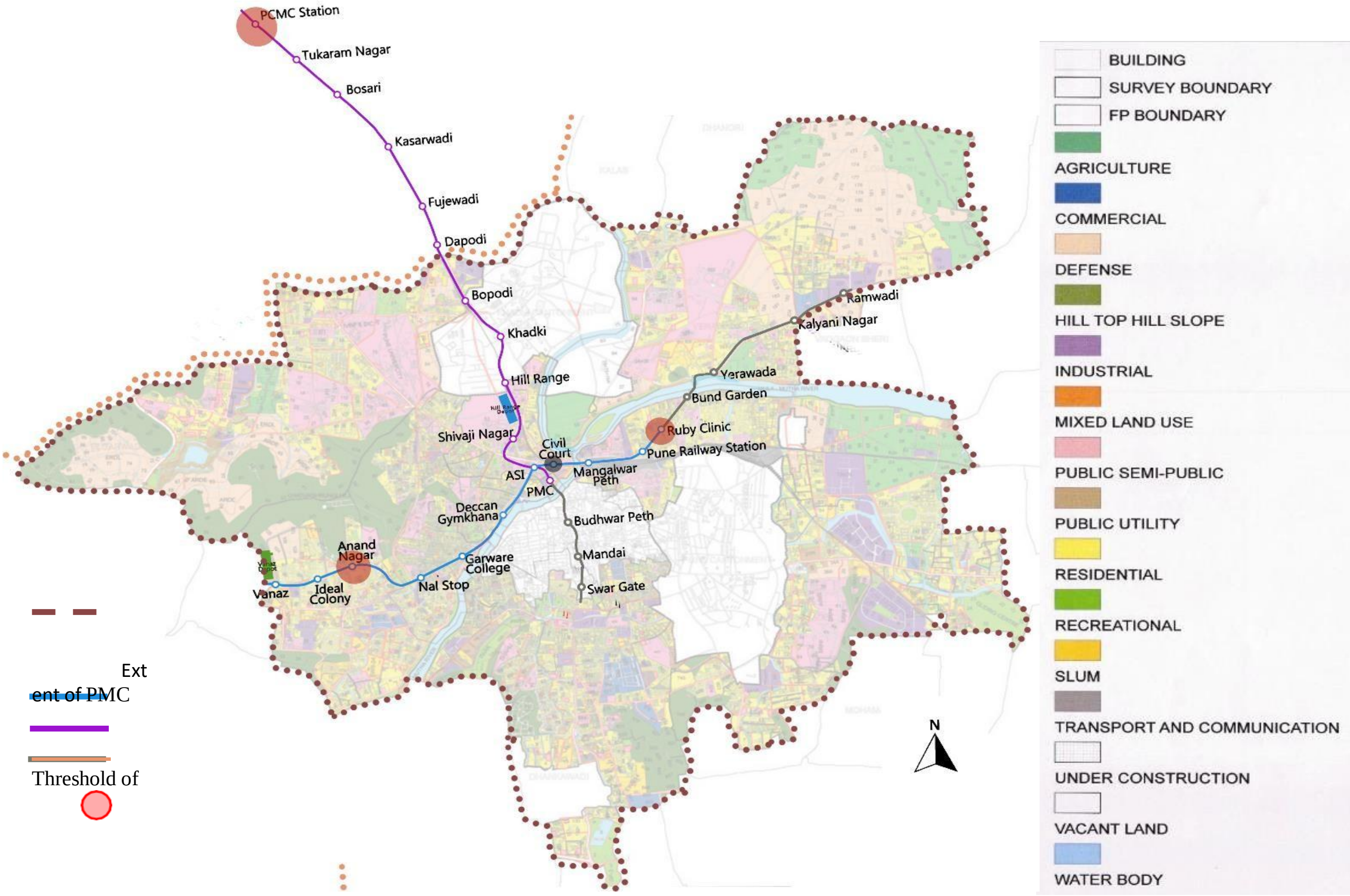


Figure 4 :. Image shows road closure provisions made for metroconstruction in Pimpri. (Credit-Prachi Bari, 2017)

Although the metro stations are located at prime locations in the city, residents living far from these areas do notfind it convenient to travel the distance especially since the parking area provided under the station is inefficient. An example of this is the accessibility of the metro station for residents living in Anand Nagar versus the ones living in Erandwane. The Anand Nagar metro station is located at the end of the street and is at close proximity to all neighbourhoods around it; residents of Mayur colony, Ideal colony, Irshadan society, etc can convenientlytravel to and fro by the metro given that the metro station is in their locality. As against this, for residents from Erandwane, the closest metro station is the Nal stop station which is approximately a thirty minute walk- this discourages the masses from travelling by the metro since it adds time to their daily commute and is not a comfortable walking distance. (fig 2)

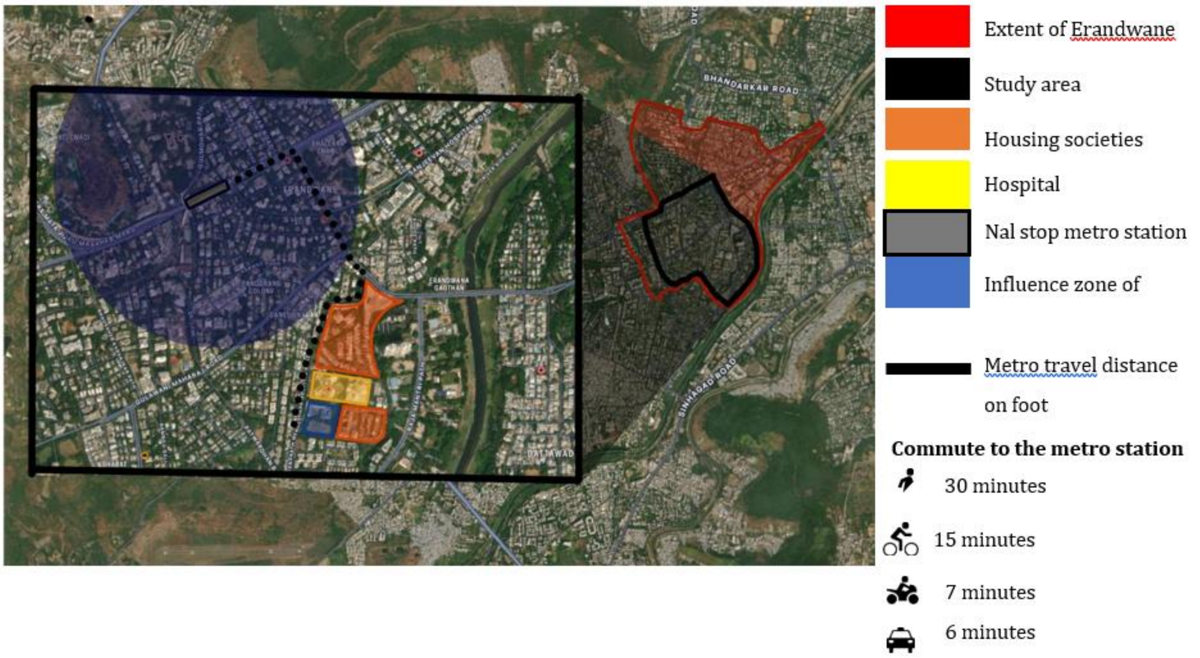


Figure 5 :. Image shows the location of some residential societies with respect to the nearest metro station in the area and the route taken byresidents to travel thereto. (Source- map sourced from Apple maps)

This situation is not resolved when an individual travels to the metro station on their private vehicle due to the lack of enough parking spaces. This leads to people parking beyond the allowable setbacks further adding to thechaos on the streets. (fig 2.1)

On site study for land use and typology across both metro lines- aqua and purple lead to the followingobservations-

Aqua line

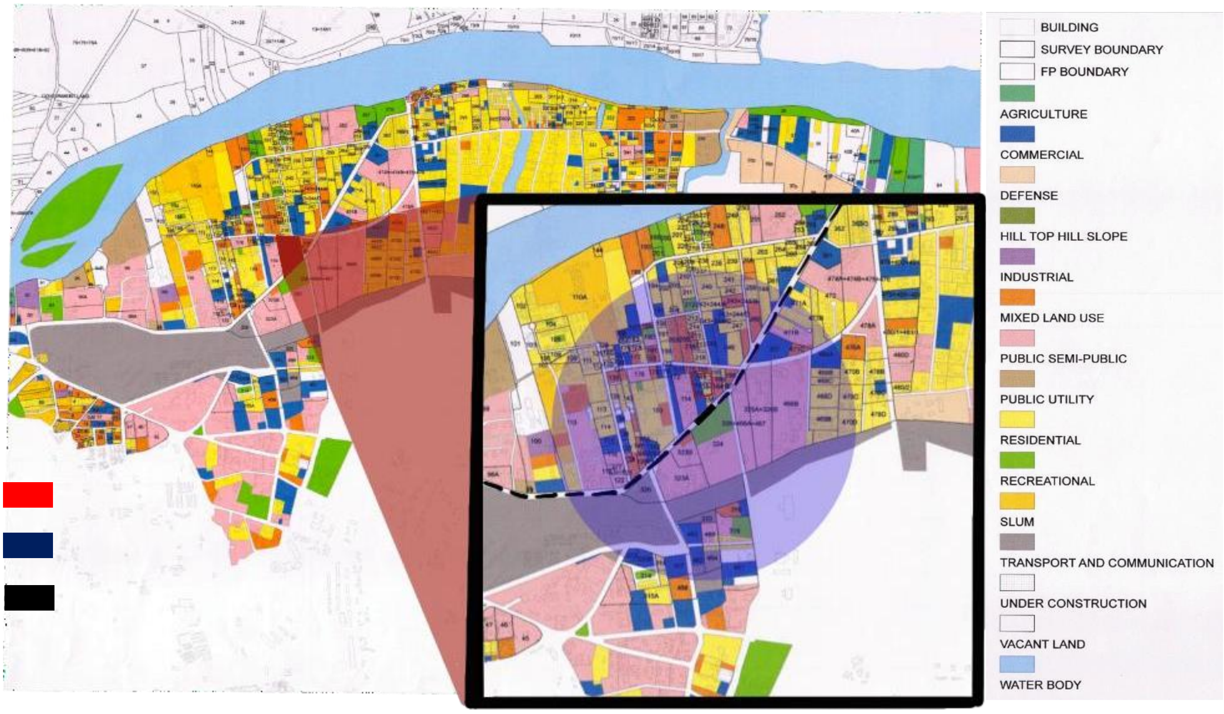
Nal Stop to Ruby Hall Clinic- residential, commercial, institutional, mixed use and industrial. Additionally, the line passes parallel to the riverside road and the Pune railway station+ residential quarters. (fig 3)

Figure 6 : showing the accumulation of two wheeler parking under Nal Stop metro station.

Figure 7:. Image shows the existing land use pattern in the influence zone of the Ruby Hall Clinic metro station. The neighbouring plots display residential, mixed use, commercial, public semi-public and recreational typologies.

The metro may lead into the conversion of the residential area adjoining the metro into mixed use. The recreational area has been developedas an effect of the metro.

(Source- DP plan sourced from the PMC website , 2023)Note: Legend as provided on the PMC website



Existing land use map for sector vi LEGEND- DP plan

200 meters	**350 meters**	**500 meters**
Existing- Residential Commercial Mixed use	Existing- Residential Commercial Mixed use	Existing- Residential Commercial Mixed use

Public semi-public Recreational	Public semi-public Recreational Slum	Public semi-public Recreational Slum Vacant land
Proposed- Commercial Mixed use Recreational Public semi public	Proposed- Commercial Mixed use Recreational Public semi public	Proposed- Commercial Mixed use Recreational Public semi public

Purple line

Civil Court to PCMC- residential, commercial, mixed use, industrial. The line running from Shivajinagar to Phugewadi has a long strip of green cover that runs on the right side (with respect to the direction of the destination). (fig 3.1)

Figure 8 : Image explains the land use patterns in the influence zone of Anand Nagar metro station. Pattern shows a majority of residential, commercial, and mixed used typologies. With the redevelopment propositions however, the residential areas along the metro line will be reformed into mixed used buildings. (Source- DP plan sourced from the PMC website , 2023) Note: Legend as provided on the PMC website.

Existing land use map for sector iii legend- dp plan

Purple line

Civil Court to PCMC- residential, commercial, mixed use, industrial. The line running from Shivajinagar to Phugewadi has a long strip of green cover that runs on the right side(with respect to the direction of the destination). (fig 3.2)

Figure 9: Image explains the land use patterns in the influence zone of PCMC metro station. Pattern shows a majority of residential and a fewindustrial and commercial typologies. With the redevelopment propositions however, the residential areas along the metro line will be reformed into mixed used buildings. (Source- DP plan sourced from the PCMC website , 2023)Note: Legend as provided on the PCMC website.

Existing land use map for pcmc

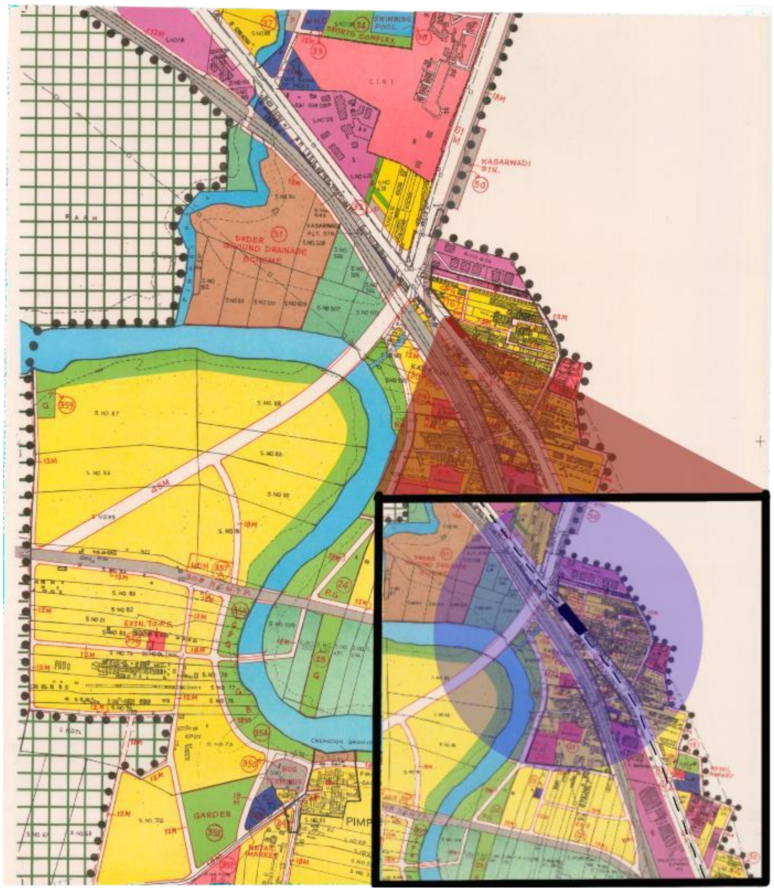
LEGEND- DP plan

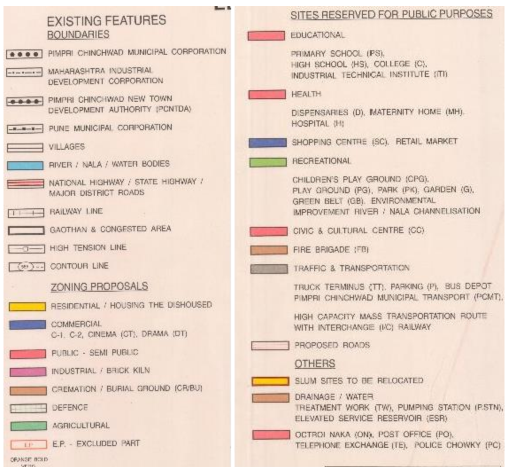
PCMC metro station

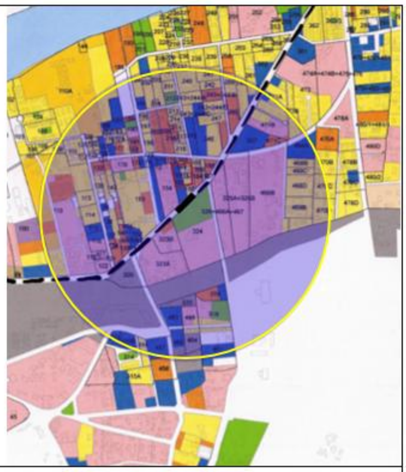
areaInfluence area of metro- 500m radius

Metro station

Metro line





		
200 meters	**350 meters**	**500 meters**
Existing- Residential Commercial Mixed use Public semi-public Recreational	Existing- Residential Commercial Mixed use Public semi-public Recreational Slum	Existing- Residential Commercial Mixed use Public semi-public Recreational Slum Vacant land
Proposed- Commercial Mixed use Recreational	Proposed- Commercial Mixed use Recreational	Proposed- Commercial Mixed use Recreational

		
200 meters	**350 meters**	**500 meters**
Existing- Residential Commercial Mixed use Public semi-public Recreational	Existing- Residential Commercial Mixed use Public semi-public Recreational	Existing- Residential Commercial Mixed use Public semi-public Recreational

Despite there being an incentive for redevelopment and the opportunity to do so, certain major activities in the city have remained unchanged. For example the industrial band stretching from Phugewadi to Kasarwadi Peth islarge scale industrial development (fig 4) which is not expected to transform due to the presence of the metro; the metro will make commute easier for the factory workers but will not relocate their workplace. Another example is the Mangalwar Peth to Ruby Hall Clinic line which runs parallel to the Pune Railway line and the consequent headquarters. (fig 4.1)

Figure 10 : Image shows the direct neighbourhood of the Phugewad- Metro station- industrial belt on both sides. (Credits- Sandip Kumar,

Figure 11 : Image shows the direct neighbourhood of the Pune Railway Station metro station- railway tracks on one side. (Image sourced from Apple Maps)

Interviews

On conducting one on one interviews with architects, developers and brokers practising in the influence areas ofAnand Nagar, Ruby hall metro stations, the following inferences have been made-

Scope for redevelopment-

Redevelopment as mentioned before, has been proposed at several locations with tremendous opportunity in housing and commercial typologies. Commercial development is observed along the main roads consisting the metro line whereas the residential typologies located in the interiors of these roads are targeted for mixed used developments. The increase in FSI from one to four and purchasing power of TDR is not quite beneficial for designers and developers given the small plot sizes.

Change in property rates-

Due to the imbalanced ratio of FSI and plot areas, the buildable area is significantly lesser than required therefore the FSI although provided, is not been given the opportunity of being consumed. This can be reversed if neighbouring plots are clubbed together allowing a larger buildable area and consequently more carpet area- the estimated proposal shows an increase from 1000 sq.m to 1200 sq.m. This will lead to a hike in property rates. Coupling residential plots require convincing of the existing residents to hand over their plots until the construction is completed. Therefore, developers and designers need to keep in mind the construction time that is required for the redevelopment projects that they take up in these localities. Interviews with brokers brought forth the possibility of fluctuations in property rates due to competition between developers in selling new development proposals. If not immediately, property values are estimated to rise by 10-20%- this will be a gradual increase as and when more metro stations and lines open up for service.

Fluctuations in rental values-

As explained above, the metro does not operate at certain major landmarks yet therefore the rental values maynot rise immediately. In an event that they do, the hike will be around ₹10,000. For commercial spaces undergoing redevelopment, rents are estimated to rise by 20%.

CONCLUSION

Studying all outlooks on the matter has lead to the conclusion that a singular metro station will have an impact only up to one kilometer around it's establishment. This means that residences, commercial properties and institutes contained in this one kilometer circle will notice an abrupt rise in property rates and redevelopment proposals. Between 200 to 300 meters from the station, properties will notice a rise is higher in comparison to the ones located between 350 and 500 meters. Once a property is 500 meters away from the metro station, the effect becomes insignificant, suggesting that the metro station's estimated range of influence on property value is 500 meters. The pricing variation's extent notably reduces with increasing distance. When the property is within 350 meters, the amount of price fluctuation peaks at that distance and then starts to decline.Areas falling out of the 1 kilometer circle cannot benefit directly from the metro given that any distance over 500 meters is not a walkable distance for pedestrians who need to do so on a daily basis. Therefore, residents who do not find it convenient to walk to the metro station will not consider availing the metro service. Walkability will not matter if a person chooses to commute to the station in their personal vehicle but this will add to the parking issue stated earlier. This means that the parking restrictions under the metro station will have to be resolved so that residents not falling under the influence zone may benefit from the metro arrangement.

Discussions with architects lead to a question of whether the metro construction, in the way it currently stands compliments the existing urban temperament of Pune city. The metro is an afterthought to problems including increasing population density in growing cities. These cities unfortunately can only grow outwards but their internal layouts cannot be tampered with. Roads cannot be widened to accommodate the construction andstanding of the pillars that hold the metro line therefore a development as huge as the metro is adjusted in the existing urban setting. Due to this, a lot of metro lines have been passing close to residential areas which hinders the privacy of inhabitants; it also adds to the noise pollution. In certain areas, slums have been relocated and acquired for parking spaces under the station. This has impacted the overall image of the city hence space design curated specifically for the metro becomes crucial.

Since the redevelopment in the city will be designed for larger densities, infrastructural provisions should be atpar with the population that they are handling; drainage, water supply, electrical supply, parking, etc. are all thefactors that require careful consideration.

In articulation, the advent of the metro construction has lead the city of Pune towards a positive advancement which in the near future will reshape the entire skyline. Redevelopment will make streetside elevations taller, the properties will get spacious but also expensive. Rental values will increase with increase in carpet area and amenities. People will demand properties around and near the metro station. It is the municipal corporation's responsibility to support such a development with the right infrastructure. Overall, the metropolitan city of Pune advancing towards a better, perhaps more expensive future will uplift the economy but not without the fundamentals that govern this change.

The flexibility and affordability in commuting aided by the metro has encouraged a lot of residents into agreements for redevelopment or to move to areas closer to the station. Since travel is feasible, a lot of people have been found with the desire to buy new office spaces. However, this solution does not come without a problem; the ongoing construction has posed a lot of discomfort for daily commuters. Roads have been narrowed and the construction noise has affected the residents. Due to the fact that all the metro lines are not operational, not every user can fully benefit from this provision however some sources say that once completed,the fully functioning metro will be a boon to Pune's overall development.

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Locational attribute as the paradigm of urban form and water shaping the native Indian settlements

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Abstract— Traditional and native Indian settlements have showcased a unique way for the selection of geographical location. It is as a paradigm of urban form and the inherent practices of water conservation such as sufficing the water needs of the settlements. They were either in the vicinity of river-valley (surface water) along with great water tanks or artificial wetlands, lakes, ponds, bunds and use of natural depression to form water tanks for the water needs. The research paper's principal objective is to explore the idea of geographical location as a static paradigm for Rajputana settlements and establish the fact that water needs were one of the parameters in the fore-front. Polarity existed in native settlements of Rajputana towns with focus on the civic zones or royal zones in the physical form and the need of water as the pertinent source for survival. Further settlements were planned in altitudinal vertical levels, tiers with a defined upper town (citadel), a middle town (optional in few cases) and a lower town, typical typology across Rajputana. The water tanks with necessary bunds were primarily in the vicinity of these vertical tiers. This feature acted as the key to water infrastructural needs. The methodology explored is comprehensive case study analysis to find out the fundamental answers to the quest. Precinct area/ heritage zone settlement data was evaluated upon w.r.t heritage town boundary and the water source used in the initiation of the settlement. Water resource vicinity was one of the defined causal considerations in development of urban forms in planned native towns of India in Rajputana region during 12th to 18th Century. This principle of urban form in native towns is still relevant with the social, cultural, environmental and political factors even for today's context as water source is the nirvana of any planned settlement.

Keywords: Urban form; Native Planning; Principles; Water; Rajputana

INTRODUCTION

Traditional and Native Indian settlements have showcased a unique way for the selection of geographical location. It is as a paradigm of urban form and the inherent practices of water conservation such as sufficing the water needs of the settlements. The traditional wisdom was to apprise for the portable water needs of the proposed settlements and thus the selection of the geographical location (Praharaj, 2014). They were either in vicinity of river-valley (surface water) along with great water tanks (such as great baths of Indus Civilization, the wisdom prevailed even in the 6th cent. settlement of Badami, Chalukyan dynasty's capital in southern India which was established in the vicinity of Malprabha river and Agastya Tank, which is an active water infrastructure till date) or duly created artificial wetlands, lakes, ponds, bunds and use of natural depression to form water tanks for the water needs (case of Rajputana towns) (Tod, 2018a).

The research paper's principal quest is to explore the idea of geographical location as a static paradigm for few of the Rajputana settlements and establish the fact that water needs were one of the parameters in the fore-front for establishing these settlements. The water infrastructure needs were taken care of within a distance range of 0.5 km – 3.5 km from the settlement as the case may be. As add on feature the natural water feature also acted as a partial defense mechanism for few of the river-front settlements in ancient times. In Harappan civilization and Mahajanapadas surface water sources were engaged for inland navigation as well as for trade with other civilizations as far as the south-east & south-west of global south (Kenoyer, 1994; Morris, 2013). Polarity existed in native settlements of Rajputana towns with focus on the civic zones or royal zones in the physical form and the need of water as the pertinent source for survival (S. Jain, 2011; Mishra, 2019).

Indian Urban Settlements has various historic phases categorized into ancient settlements, native settlements, invasion settlements and modern/ contemporary settlements (Walter A. Fairservis Jr., 1961). Ancient settlements are in the phase of 2500 BC to 300 BC, Native settlements are in the phase of 500 BC to 1700 CE, Invasion settlements are in the phase of 1000 CE to 1947 CE, Modern/ Contemporary settlements are in the phase after 1947 CE. Reason behind the categorization is the context in which these settlements were created and flourished. They have certain character and morphological phenomenon to them with underlying planning principles of urban form. Though the temporal layer has its effect on the spatial layer still in present day condition some learning's can be augmented. The study area for this paper is Rajputana region which belongs to the Native settlements category and phase.

Needs and objectives

Significant native Indian town planning practices with respect to geographical location and water resource nexus has not been adequately studied so as to substantiate for solutions of issues arising of current practices. Water has been a key component for the sustenance and survival of native settlements since antiquity (Dhiman & Gupta, 2011; Hussain et al., 2014). Indian settlements were planned accordingly to be in the vicinity of water resource either surface water or collected through water tanks which harvested rain water. Further the settlements were planned in altitudinal vertical levels, tiers with a defined upper town (citadel), a middle town (which was optional in few cases) and a lower town. The water tanks with necessary bunds were primarily in the vicinity of these vertical tiers. This is the typical typology across the Rajputana towns. This feature was one of the key water infrastructural amenities of the settlement.

Following are the objectives for this study:

- To study relationship nexus with water source and the settlements.
- To evaluate the inter-relationship of urban form and the water infrastructure.

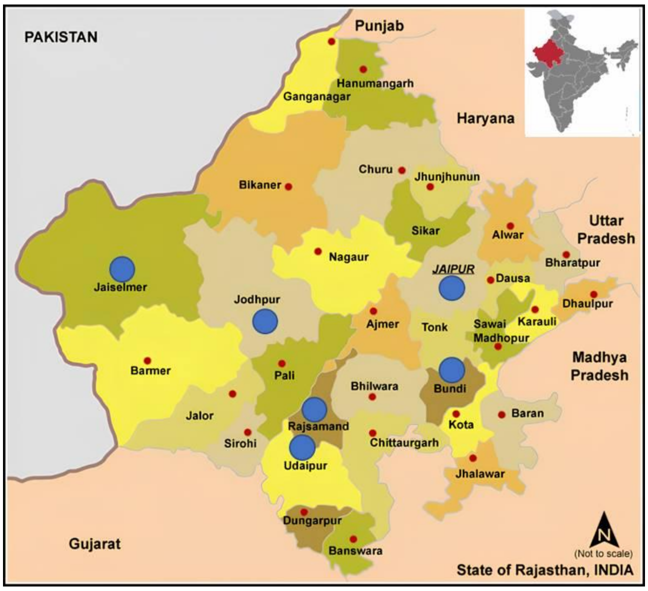

Figure 1: : Rajasthan state with the districts and the six historic core areas for the present study (Top Right) Map of India showing Rajasthan state

LITERATURE REVIEW

Geographical setting is one of the predominant factors which initiate's the footprint of any native settlement (B.B Dutta, 1925). In the present study we focus on the north-west frontier province of India that is the state of Rajasthan as shown in Figure: 1 below. The cities which are being explored in this study are Jaipur (18th CE), Jaisalmer (12th CE), Jodhpur (15th CE), Rajsamand (17th CE), Udaipur (16th CE), and Bundi (14th CE). Selection of the study area is owing to the fact that Rajputana Towns of the 12th to 18th CE and the region in its urban form and built form both has stood the test of times against Islamic and Colonial invasion.

12th CE Onward urban settlements were established in the Mewar, Marwar and other regions of Rajputana which also has footprints of few Harappan civilizations in the region (Deshpande & Shinde, 2006). Indian peninsula has native settlements in the area what is now known as Rajasthan State. Predominant feature is the locational attribute w.r.t the context and natural settings for water availability respected in the city layout (Ching, 2011). Figure: 2 below shows the photo montage of the six cases being explored upon to validate the point that locational attribute has been one of the major paradigms of urban form in native Indian settlements and the practices of planning. Traditional water harvesting methods in Rajasthan are Kund/ Kundi in areas of Thar Desert and western Rajasthan, Kuis/ Beris in western Rajasthan, Baoris/ Bers community wells across Rajasthan, Jhalaras step wells predominant in the Marwar region, Nadis a dug-out village pond, Tobas a ground depression with a natural catchment area, Tanka an underground cistern mostly used in Bikaner region, Khadin/ dhora harvest surface runoff water for agriculture, Vav / Vavdi / Baoli / Bavadi, traditional step-wells for community water needs, Naada / bandha found in the Mewar region of the Thar Desert, Paar a common place where the rainwater flows from the agar (catchment) and in the process percolates into the sandy soil (Dhiman & Gupta, 2011; Hussain et al., 2014). This traditional wisdom with the appropriate method to the region was put to use across the urban as well as rural landscape of the state since antiquity.

Jaipur precinct area was built in 18th CE by Maharaj Sawai Jai Singh II and planning of Jaipur walled city is based predominant on grid iron. It was a Greenfield town built with city palace and other blocks for residing tradesmen and was envisaged as the trading gateway for the Rajputana region. It has two major water bodies Talkatora Lake in the heart of the precinct and Jal Mahal Lake at the NE periphery of the settlement. Talkatora Lake was fed with three sources of water that is rain water, fountain water (from Jai Niwas garden) and storm water run-off (from the adjoining City Palace). Jal Mahal lake was fed with rain water (Akhilendra B. Gupta, Renu Jain, 1999; Mishra, 2019; Tod, 2018c).

Jaisalmer was built by Raja Rawal Jaisal in 12th CE. Maharawal Gadsi in 14th CE built Gadisar Lake in the SE periphery of the plateau town for water needs which was fed by rain water. Historical precinct was on the highland which is an active fort town till date. When the lake was full, extra water flowed to lower level and further to next level, this way the nine lakes worked. Other than this wells, step-wells and johads were other source of water in the city (Mukhopadhyay & Devi, 2018; Tod, 2018b).

Figure 2 : Photo Montage of the six cases with respective water infrastructure at the initiation of the settlement.

Jodhpur was built in 15th CE by Rao Jodha a chieftan of Rathore clan. Mehrangarh Fort is the principal citadel which is on the highland. Twin lakes of Ranisar and later Padamsar Taal in NW end were built for the water needs of the citadel, town and the region (Agarwal & Narain, 1992; Tod, 2018b).

Rajsamand town was built in 17th CE by Maharana Raj Singh I of Mewar. Lake Rajsamand (also known as Rajsamudra Lake) is between two towns of Rajnagar and Kankroli and was the result of dam construction across river Gomati, Kelwa and Tali in 17th CE. It was to take care of the famine and provide livelihood to the masses also providing canal irrigation to the farmers. Nauchoki is on the southern end adorned with ghats and beautiful pavilions (Outline Development Plan of Rajsamand, 2014; Tod, 2018a).

Udaipur was built in 16th CE by Maharana Udai Singh II as the new capital of Mewar kingdom in the fertile crescent of Girwa valley. Pichola Lake existed since 14th CE owing to dam construction on river Kotra and the king built the City Palace and the city along its banks. Along with this Fateh Sagar lake was built in 17th CE for irrigation needs. Water needs of the region were taken care of from these two lakes. Surrounded by Aravallis range Udaipur also has four more lakes in the regional vicinity Rangsagar, Swaroopsagar and Dudh Talai (Surana, 2017; Tod, 2018a).

Bundi town was built by Rao Deva in 14th CE, the citadel Taragarh Fort is situated on the hill top. Lake Nawal Sagar is on the SW end of the town which was main source of water for various step-wells in the city. It houses a temple and various ghats all around. Lake Jait Sagar is on the NE end near Sukh Mahal which was also built to take care of the water scarcity in the region and irrigation (N. K. Jain et al., 2022; Tod, 2018a).

Figure: 3 below illustrates the above explained native settlement location and water source nexus through Google earth imagery. This is like location-allocation of settlement and the water source as envisaged by Rajputana ancestors to suffice the water needs of the citadel and the town. Along with these primary sources these rulers had wisdom to build wells, step-wells, johads etc. to supplement the water availability. Originally incepted the two community water tanks at Badi Choupar and Choti Chaupar were closed in 19th century after the introduction of piped water supply in Jaipur walled city. This notion and acceptance that the traditional wisdom of water infrastructure is not enough and cannot now take the tests of time is the biggest dichotomy. In particular this wisdom has been steadily and in due course of time being discarded in the urban areas of the state. Few exceptions do exist where in older water infrastructure in marginal numbers is still in use for the water stock

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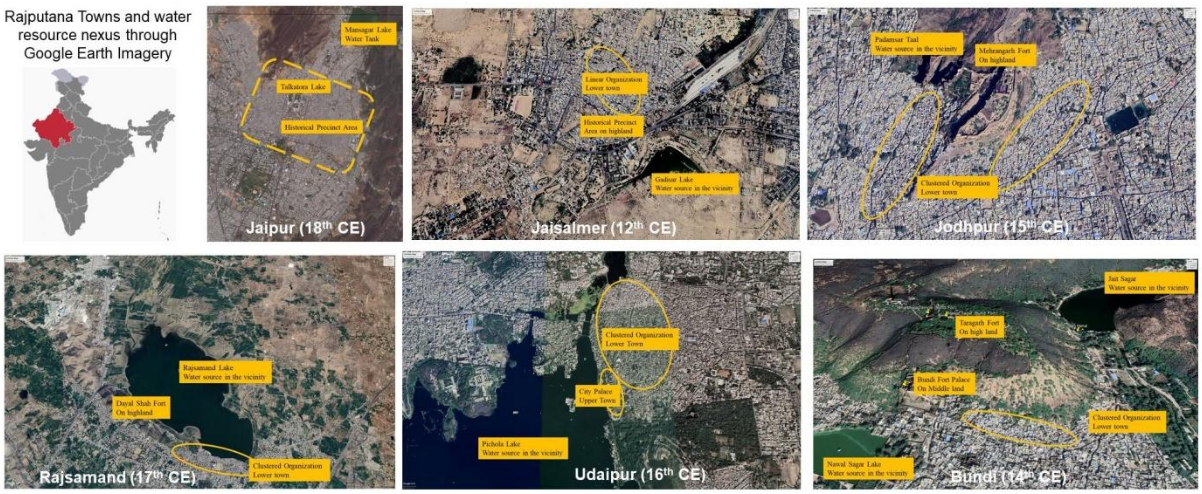

Figure 3: Rajputana Towns and water resource nexus through Google Earth Imagery: Top Left to Right – Jaipur, Jaisalmer and Jodhpur; Bottom Left to Right – Rajsamand, Udaipur and Bundi.

Materials and methods

The methodology explored is comprehensive case study analysis to find out the fundamental answers to the quest. Precinct area/ heritage zone/ walled city's settlement data has been evaluated upon w.r.t initial heritage town boundary and the water source used in the initiation of the settlement. Many of the cases still have this water resource infrastructure active in Rajputana towns. Further structured interviews with six experts were conducted to validate the understanding in the native practices of planning w.r.t the year of inception of the town. Critical appraisal after this is presented in Table-1 in the next section. Conceptual flow diagram for the methodology is as shown below in Figure: 4

Figure 4: Conceptual flow diagram for the methodology

Results and discussions

Native Indian towns show high standard of planning principles as depicted in limited literature available. Indigenous planning principles are not to be archived, but to be updated and used for current city planning and design (Saifullah Khan, 2014). The long gap of in the research in the indigenous principles led two major complications and limitations in planning practices (Smith, 2007). First, the current planning is directed to western advocacy since there is no updated research on the Indian town planning principles and practices (Joseph, 2018). Second the current generation is not able to handle rightly the redevelopment of historic settlements and cities in absence of a clear theoretical model.

The native Indian towns established followed the treatise of ancient nagar-vidhana. Most critical factor and the geographical locational determinants were of the availability for water source and thus its disposition. Water infrastructure was given one of the most important dimensions in the layout and setting of the ancient settlements (Tod, 2018a). Figure-5 below shows the three categories of town – water source model; first is, lake at the grade along-with the palace (case of Jaipur), second is, lower tier lake & fort/ palace at the highland (case of Jaisalmer, Jodhpur and Bundi) and third is, lake front with fort/ palace on the highland (case of Rajsamand and Udaipur). Table: 1 shows the dimensional proximity to the inherent water source with critical appraisal of its nexus to the citadel and the native town

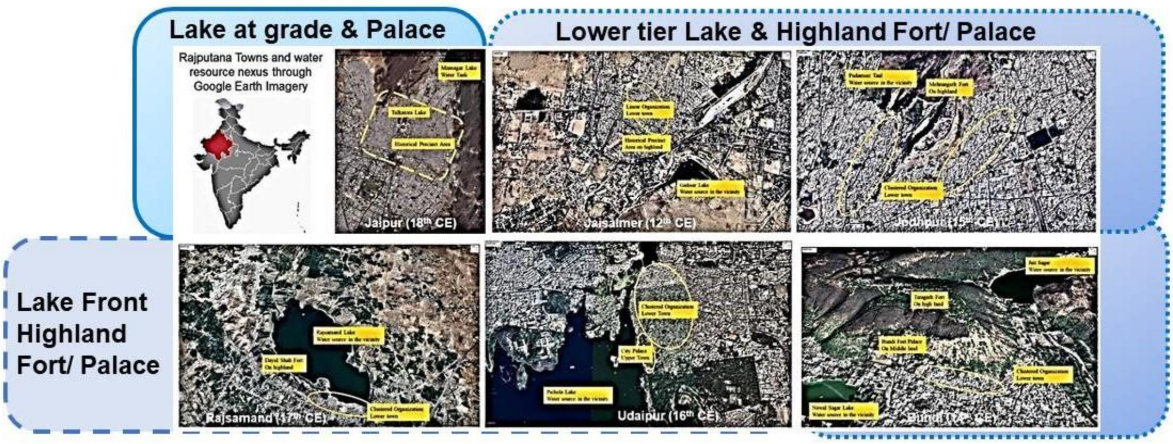

Figure 5: Town-Water source model (Top Left) Category-1 Jaipur, (Top Center & Right, Bottom Right) Category-2 Jaisalmer, Jodhpur & Bundi, (Bottom Left & Center) Category-3 Rajsamand, Udaipur

Table 1: Dimensional proximity of the water source to the citadel and the native town

Precinct/ Citadel/ old Town area	Era of Town's inception	Water source in the vicinity at inception	Proximity from the Citadel and town (in mts.)	Critical Appraisal
Jaipur	18th CE	Talkatora Lake	500-1800	Three water infrastructure which tested the scale of times for more than a century
Jaisalmer	12th CE	Gadisar Lake	800-1500	A unique system of nine lakes in vertical tiers for water flow
Jodhpur	15th CE	Ranisar and Padamsar Taal's	300-1000	Twin lake system complimenting the water stock
Rajsamand	17th CE	Rajsamand Lake	200-800	Resultant of dam construction. Dual benefit as it also acted as defense water front.
Udaipur	16th CE	Pichola and Fateh Sagar Lake's	200-1800	Twin lake system to take care of community and irrigation water needs
Bundi	14th CE	Nawal Sagar and Jait Sagar Lake's	200-1000	Twin lake system to take care of community and irrigation water needs

CONCLUSION

Water resource in the vicinity was one of the defined causal considerations in development of urban forms in planned native towns of India in Rajputana region during 12th to 18th Century. This principle of urban form in native towns is still relevant with the social, cultural, environmental and political factors. Even in today's context water source is the nirvana of any planned settlement. As a concluding remark for the research presented traditional wisdom was having the ideology of "A local problem with local solutions" which is quite different from today's where a local problem sought remote solutions. Multiple studies and national as well as international reports have established that water is a scarce source for mankind. We as a collective have one planet with limited water resources, though the abundance lies in water harvesting and conservation. Traditional wisdom of settlement location and water allocation nexus from the Rajputana towns has shown us the methods which can also act as way forward..

CONFLICTS OF INTERESTS

No conflict of interest was declared by the authors.

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Escalation of Architecture Towards Biomimicry

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Abstract— Sustainability being the main focus of building design is collaborating for better results to achieve or built nature into life to reduce the problems face by the humankind. The solution to the issue was to adopt the concept of life of living beings into building design. So, they came up with the term Biomimicry which involve the nature itself to be the function of the structure. The use of advanced technology in Biomimicry increased the result to enhance ecological sustainability towards the new way of living within the limits of the environment and they even adjust to the obstacles in climatic changes. Shaping the structure, inspired from nature, by mimicking the adaptive strategies to gain new sustainable solutions and energy efficiency techniques. The analysis states that the focus of inspiration was to mimic the function of the organisms into the structure by concentrating on the aesthetic design approaches and strategical solutions. The paper aims to focus the biomimetic approach towards architecture linking different biomimetic approaches to adapt the climatic changes by referring the case studies and finding the sustainable approaches and passive thermoregulation in different climatic zones. Qualitative methods are used as the data collection. The research paper shows the descriptive analysis methods to prove the effects of nature in structure and urban life to create environment conscious and energy-efficient design. It concludes that integrating the principles of biomimicry can give enormous outcomes to the structure or for the life

Keywords: Sustainability; energy efficiency; cost-effective solution; building envelopes; passive thermoregulations

INTRODUCTION

The earth is developing for last billions of years and in the chain of life, humans are lately added into evolution chain. Despite due to the evolution in advanced technology still human faces obstacle to diminish pollution and environmental issues due to increase in demand of new products. Hence creating a threat to depleting natural resources. According to the researches, nature evolves itself to solve the problems caused by humans like the plants and animals have adapted itself to adjust in the harsh climate and deal with the limited resources. So, the nature's form, system and processes can be imitated to solve the obstacles (AlAli, et al., 2023).

Adopting sustainability is the leading role to overcome the challenges which gives a new figure to the society by adopting nature into it. Nature's principles are a mode to achieve sustainability by giving a new approach to solve the environmental issues (Wahhab et al., 2022). Sustainable structures give less impact to the environment increasing the energy efficiency and lessens the impact of economic growth. The evidences from researchers show that the survival is possible through evolution, adaptation and development of the world by using nature as the inspirational source to solve the challenges. And this inspirational term is known as "Biomimetic" which takes nature as the learning platform and imitates them to create sustainability. This concept can lead to solutions for architectural design in different scale of project (Hafizi et al., 2022).

Biomimicry has expanded in every field from smaller to large scale projects to achieve sustainable society. It has become a multidisciplinary subject which focuses on new innovations to attain sustainability. Biomimetic develops solutions from the living organisms which function both externally and internally to have energy efficient buildings. This has been connected to biology to transfer the function of the organisms into the structure to follow sustainability (Uchiyama et al., 2020). It has several other terms like Bionic, Biomimetic, Bio-morphism, etc. but biomimicry differs by the act of imitating nature by focusing to preserve nature thus by giving priority to the function rather than form (AlAli et al., 2023).

Theoretical background

Origin of Biomimicry:

Imitating the art of nature to solve the solutions of humankind was not a new practice. Earlier human depended on nature for the facility of food, shelter and other tools for their survival. The nature itself sustains by meeting their needs and provides sustainable remedies to their obstacles. The past records of bio-inspired technologies are listed:

- Flying machines - designed by Leonardo da Vinci known as Ornithopter where he mentioned the inspiration from bats, kites and birds. Though it was just a sketch and never built, the first flight has been recorded in 1942. Afterward, there has been great successful inventions of flights (Fig.1).
- Velcro - Designed by Georges de Mestral, got inspired from the removable and easily attachable feature of the seed burrs from burdock plant. This ideation led to the invention of hook and fastener after 25 years.
- London's Crystal Palace – Designed by Sir Joseph Paxton in England, got inspired by the leaves of Giant water lily.
  (Oguntona et al., 2017)

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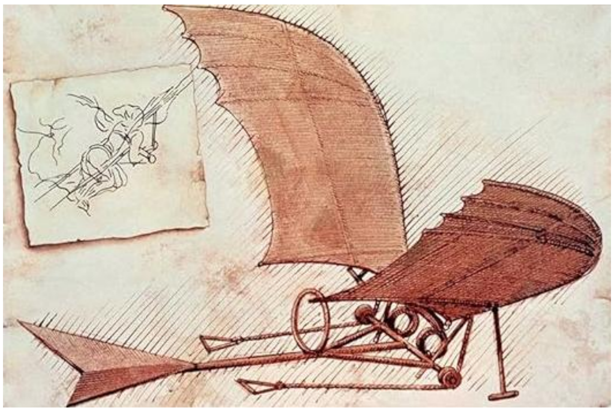

Figure 1 : Flying Machine

Biomimicry

The Biomimetic approach aim to adapt nature into architecture to bring out life to them for better solution since the word biomimetic terminologies comes from two Greek works of bios and mimesis which means life and imitate respectively. For the past 3.8 million years, the evolution and survival of natural beings is the most efficient proof for the changes in the adaptation of the ecosystem (Hafizi et al., 2022). Biomimicry got popularised from the book "Biomimicry: Innovation Inspired by Nature" written by Janine M. Benyus, suggesting to be terming biomimicry in different term which meant to be the inspiration and knowledge for solving the challenges (Oguntona et al., 2017). To bring out natural solutions into design the barriers approached should be studied due to the complexity and multidisciplinary actions. Therefore, there are biomimetic principles:

1. **Adaptation –**

- Morphologically – changes in the body

- Physiologically – how the changes occur
- Behavioural – how the organisms adapt to survive

2. **Design approach –**

- Top-down – problem is identified first and then the solution is being found by finding the similar conditions adopted by an organism to implement into design
- Bottom-up – the solutions are already known and is implemented based on the problems (Fig.2)

3. **Level –**

- Organism – forms to survive the environmental changes
- Behaviour – the action or behaviour is mimicked
- Ecosystem – combining both the levels

4. **Strategies –**

- Dynamic – macro scale presenting the motion
- Static – micro scale (Hafizi et al., 2022)

Energy efficient buildings depend on the utilization of plant and animal existence to imitate the concept of feather in structure insulation even preventing from excessive heat loss by using heat recovery system which is imitated from the circulation of cross current in legs of penguins and reindeers (AlAli et al., 2023).

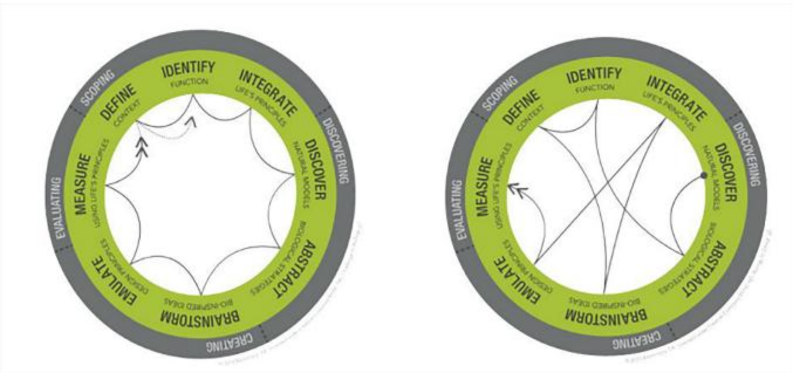

Figure 2 : Biomimicry approaches representation: problem based (left) and solution based (right).

Biomimicry in architecture

Building envelope

The role of envelopes has played a crucial role in exchange of heat and fresh air, providing views and daylight and protect the indoor environment from extreme climates. The concept of polyvalent wall was introduced by Davies in 1981. It has multiple layers of glass which can produce energy for the structure (Xing et al., 2018).

Concept of adaptive measures in structure is meant that the envelope has the ability to face the climatic conditions to attain thermal comfort and decrease the consumption of energy (ElDin et al., 2016).

- Plant cell walls

The tissues of plants provide structural integrity such as the optimization of cell wall in xylem tissue provides load bearing, parenchyma tissue for shape and cell wall structure to increase the turgor pressure control. The cells of the plants with their rigidity maintains their shape and protect the elements. So, the functions of these cell are provided in the building envelopes to produce energy naturally and adapt the changes as per the condition (Table1). There are radical changes which the plants itself makes to themselves to survive the environmental challenges. Programmed cell death (PCD) regulates the dismantling of unwanted cells which is crucial for the survival and growth and various other role like embryo development, formation and maturation of cell types and tissues and plant reaction or adaptation to the conditions (Xing et al., 2018).

PCD originated from plants but plants and animal PCD share characteristics and several differences to exist. The Plant cells are not phagocytic due to the presence of thick cell wall and has cell

Table 1 : Analogies

Analogy in key function	Plant cell walls	Building envelopes

Protection against external elements	• Protection against biotic stresses and abiotic environmental stresses. • Separate cell interior from the external environment • Prevention of water loss	• Protection against external elements (wind, noise, solar radiation, rain, cold) • Maintaining the indoor climate
Exchange of heat, air and water	• Enabling the transport of materials and information from interior cell to exterior cell and vice versa. • Diffusion of substances into and out of the cell • Design of pits for the flow of fluids and control of cavitation	• Conduits for plumbing, electrical and other services • Fenestration, ventilation, and passive air and moisture exchange
To define shape and space	• Protection against biotic stresses and abiotic environmental stresses • Providing structural support • Prevention of rupturing of cell due to turgor pressure	• Defining space and function • Proving structural support and identity.

Table 2 : Demonstration examples of design

Design Principles	Building example	Technologies
Permeable and multiple functioning	• Cellular envelopes • Dynamic insulation materials • Transpired solar collector • Porous reflective cool roof • Polyvalent wall • Air filtration to improve air quality	• Cellular structures serve to be both a barrier and structure. • Allow heat exchange through porous façade • Providing heat exchange and air flow through perforated steel skin • Porous roof structure with oriented holes to re-radiate heat • To generate energy with multiple layers of glass and PV • Absorption of vapors and Vocs through Porous materials.
Shape changing adaptation	• Hygromorphic materials • Mechanical responsive facades • Kinetic skin • Materials which change shape • Dynamic light transmittance glazing	• Response driven towards the shrinkage and swelling of wood triggered due to moisture changes. • Dynamic shape changing facades with mechanical actuators • High tensile strength with low bending stiffness of lamellas allowing elastic deformations • Shape changing polymers, alloys or hybrid materials, for example, EAPs, PZTs • Electrochromic glazing materials

Design Principles	Building example	Technologies
Biosynthesis process	• Green buildings • Solidified granular materials • Use of multi-functional biomaterials by buildings. • Cellophane house	• Green roofs, green walls and 'tree houses' • Preventing desertification by cementation of sand dunes to create a network of sand dunes. • Mycelium building materials blocks and slime mould to locate optimal space or routes • Using discrete components in reversible process.

autonomous process where corpse is cleared. The dying cell breaks down the body and places it in vacuole to rupture. So, for mimicking the PCD mechanism for the deconstruction requires a more radical animal PCD approach (table 2) (Xing et al., 2018).

Inspiration from spine

The vertebrae are made of both organic and inorganic components and are found in both human and animal bodies. Despite being hard and rigid, they can withstand heavy loads, allowing birds to fly and sea creatures to swim around and protecting the internal organs of the creature despite the growth and development throughout its life. In nature, the spine and ribcage cooperate to ensure a species stability and survival. The same ideas are crucial in construction that were constructed by humans. As a result, designers have long been interested in human spine and skeleton. The spines special strength comes from the balanced function of the comprehensive and tensile elements working together to maintain the stability of the structure. For aquatic and terrestrial animals to exist and migrate, the spine has evolved over time to withstand various physical and atmospheric demands. The spine has a riveled potential from which bionic technologies are inspired including strength, stability and flexibility (Golkar et al., 2021).

High-rise buildings

Talls buildings shows smaller footprint and roof area and it's the consequence of population growth and due to scarcity of land. Three classifications of buildings:

- 50-300m tall buildings
- 300-600m supertall buildings
- above 600m mega tall buildings

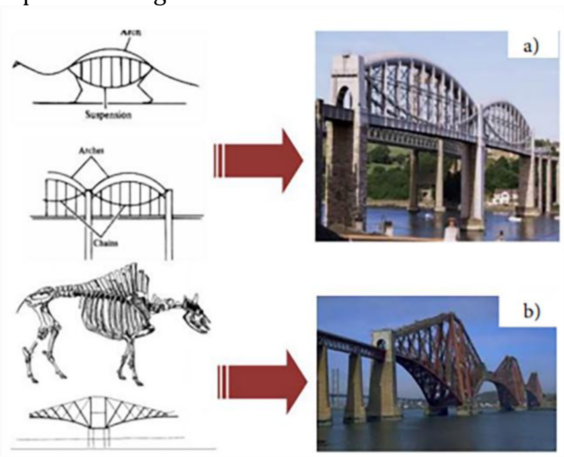

Figure 3 : Concept: a) Royal albert bridge, b) Forth bridge

Tall buildings give more accommodation and amenities and are provided in modern high-rise buildings for social interaction for easy accessibility. Even this can give disadvantages that is feeling of isolation and even private balconies are not functional in maximum time due to strong winds or small in size. Use of energy consumption, CO2 emissions and material use has been increased widely which leads to the importance of sustainability. Biomimicry can reduce environmental impact, such as deforestation and pollution by reusing resources and utilizing renewable energy. Tall buildings can function like living organisms, producing no waste and addressing environmental, sociocultural, and economic issues. This approach towards biomimicry architecture promotes sustainable solutions with more energy efficiency, and less material use (Mirniazmandan et al., 2017).

Helically tubular structure

Porous materials and cellular solids are widely used in engineering due to their light weight, high specific strength, energy absorption, permeability, efficient material consumption, thermal insulation and sound absorption. Biological material uses eight structural design elements: fibrous, layered, cellular, tubular, gradient, helical, sutured and overlapping. These structures self-assemble into complex hierarchical structures with outstanding mechanical performance. Helical structures provide excellent strength and toughness by stacking fibril bundles at a constant helix angle. Tubular structures, like dentin, horse hooves, and sheep horns, are known for high impact resistance and energy absorption. Recent efforts have been made to mimic and optimize these structures through various fabrication methods, with additive manufacturing (AM) being the most commonly used approach. This combines helical, tubular, and cellular design elements to create bio-inspired helically oriented tubular (HOT) structures. These structures consist of stacked tubular structures at a constant helix angle and were fabricated using thermoplastic polyurethane (TPU) and investigated for mechanical properties, energy absorption performance, and recoverability. Finite-element analysis (FEA) simulations were used to understand structural deformation, stress distribution, and energy absorption mechanisms (Tung et al., 2022).

CASE STUDIES

It's an example of behaviour level which indicated a breathing skin. It's been abstracted from the nature of termites and termite mounds. Control of climate was the main motive inside the structure which fluctuated from 40 degree C to less than 0-degree C. The termites maintain a constant temperature (30 degree C) by creating thick and insulating walls to maintain a flow of air from bottom holes to top openings. It creates a stack effect where the convective air flows from cool to warm. The termites are continuously adjusting these apertures to and occasionally they add damp dirt that promotes cooling through evaporation. The structure is based on termite mounds passive ventilation strategies and temperature regulation. The complex consists of two buildings that surround an inner atrium. Limited windows, overhangs, and building mass helps to prevent heat gain, while the architect used night cooling, thermal storage and convective air currents to keep temperature moderate (Fig.3 & 4). The buildings heavy mass and basement rock storage absorb heat during day, while cool air is allowed at night through roof vents and hollow floors. (ElDin et al., 2016).

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Figure 4: Eastgate Centre

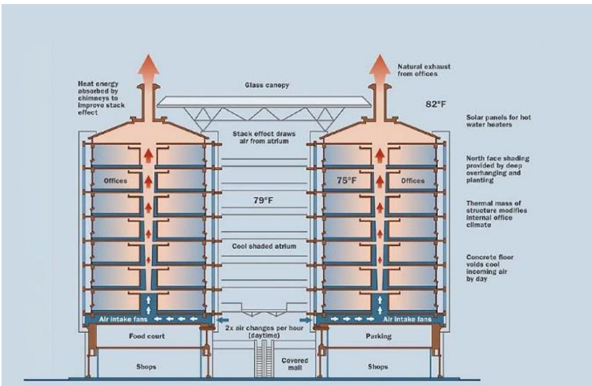

Figure 5 : Eastgate Centre section

CONCLUSION

The research based on the flexibility of architecture seeks to find the enormous and impossible ways to find the solutions to the problems faced nowadays. Through biomimicry, it is possible to find solutions to the environmental challenges through nature. Imitating the nature into structure and designing, its results into improving the ecosystem. Applying the principles of biomimicry, the adaptive behavior of structure, enhance the thermal comfort, no waste production, renewable energy consumption and many more can be achieved by mimicking the system of termite mounds or self-cooling mechanisms of desert plants. The designs have shown a breakthrough in lightweight structures inspired from lattice of bird bones and water repellent surfaces inspired from lotus leaves. These can reduce the environmental footprint of human-made systems. Biomimetics can create numerous design solution which can help reduce the resource consumption and waste production in various fields, devices and structures. Evolution provokes for better solutions by creating multifunctional and self-adaptive solutions through mutation. This has a wider scope form urban level to rural level by imitating the functional system of living organisms into the design by maintaining the ecological balance on the concepts of organism's behavior, ecosystem, and function. The slow process can lead to a sustainable environment.

Thus, the biomimicry contributes towards converging science, creativity and sustainability offering a sustainable and resilient future. By harnessing the natures given solutions, we can protect, sustain and restore it.

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Investigating Efficiency of Courtyard Designs in Western Indian Havelis

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Abstract— The courtyard, a fundamental element ingrained in the traditional residential architecture of India, has left an indelible mark across various regions, from the opulent Havelis of Gujarat to the rural houses of Bengal. This article explores the architectural and social dimensions of courtyards in western Indian Havelis, addressing a notable gap in existing literature. Notably, it scrutinizes the dimensions, particularly the height-to-width ratio, in comparison to current building guidelines. The methodology involves an in-depth investigation of four specific Havelis in Rajasthan, examining their historical timelines, unique features, and contemporary use. The analysis reveals diverse spatial hierarchies, gender dynamics, and multifaceted uses within Haveli courtyards. The selected Havelis - Mandawa, Nathmal Ji ki, Poddar, and Piramals - showcase distinct architectural philosophies, emphasizing the importance of front and back courtyards. Comparative assessments highlight variations in length-to-height and length-to-breadth ratios, providing insights for architects. Importantly, the absence of specific courtyard height guidelines in the National Building Code of 2016 is underscored, emphasizing the need for attention in contemporary architectural discourse. In conclusion, this research contributes to the discourse on courtyard design by unraveling the architectural significance and social dynamics within western Indian Havelis. The findings serve as a valuable resource for architects, urban planners, and preservationists, offering inspiration to create contemporary spaces rooted in the cultural and historical essence of traditional courtyards. Further exploration is encouraged, extending this research to investigate courtyards in vernacular architecture.

Keywords: Built environment; Courtyard; Cultural identity; Haveli; Vernacular architecture

INTRODUCTION

The courtyard, an integral element deeply woven into the fabric of traditional residential building design in India, stands as a distinctive and defining feature across various regions of the country. Its influence extends from the opulent Havelis of Gujarat and Rajasthan in Western India to the quaint rural houses of Bengal in the east and the traditional Wadas of Maharashtra in the central part of the country. Courtyards also grace the architectural landscape of the southern regions, as seen in the Nalukettu of Kerala and the Chettinadu houses in Tamil Nadu, contributing to the diverse and rich tapestry of courtyard design. Tracing back through the historical epochs of our civilization, the presence of courtyards in Indian culture dates back to the Indus civilization of the 3rd millennium B.C. and further finds expression in the Vedic architecture of 1500 B.C. Rooted in the principles of the 'vastu' system, it is advocated that a house's functional spaces should be enveloped by a central open space known as 'Bramha'. This central area serves as the nucleus for a myriad of household activities, ranging from mundane daily chores to sacred rituals and cultural practices, such as utensil cleaning, laundry, and worship. Beyond its utilitarian roles, the courtyard plays a pivotal role as a microclimate modifier, actively regulating temperature and ventilation. This harmonious interplay between the built environment and nature enhances the overall living experience, illustrating the enduring significance of courtyards in Indian architectural heritage.

While existing literature has delved into the architectural marvels, sustainability, green design features, art styles, cultural richness, convervation and adaptive reuse of Indian havelis (Asghar 2021; Khan 2010, 2016; Liansangpuii et al. 2023; Mehmood and Jan 2022; Routh, Bhavsar, and Patel 2022; Singh et al. 2022; Verma, Kamal, and Brar 2022), there is a notable gap in the focus on architectural elements that shape social dynamics, particularly with regard to courtyards. Additionally, the investigation into whether the dimensions of these courtyards, especially the height-to-width ratio, align with current building guidelines has not been addressed. This study explores the spatial configurations, gendered experiences, and psychological impacts of courtyard designs in Western Indian Havelis by grounding the analysis within three theoretical frameworks: Space Syntax Theory, Gender and Space Theory, and Environmental Psychology. These frameworks offer valuable insights into the social, architectural, and psychological dimensions of space, particularly in relation to historical structures like Havelis, where cultural norms and social hierarchies play significant roles in shaping architectural elements. This article aims to address this gap, providing valuable insights that can serve as guidelines for future architects, especially in the design of contemporary buildings.

The subsequent section provides an in-depth exploration of the methodology employed in this research. section 3 scrutinizes the social dynamics within courtyards and examines the dimensions and other characteristics of western courtyards. The section concludes with a comparative assessment against current building guidelines, followed by a discussion. Lastly, the article wraps up with a consideration of future research prospects.

Theoretical Framework

The theoretical framework for this study is grounded in three key areas of inquiry: Space Syntax Theory, Gender and Space Theory, and Environmental Psychology. Each of these frameworks provides a unique lens through which to analyze the spatial, social, and psychological dimensions of courtyard designs in Western Indian Havelis. By situating this study within these established bodies of knowledge, it seeks to address the gaps in the current literature regarding the intersection of architectural design, social dynamics, and human behavior.

Space Syntax Theory, first developed by Bill Hillier and Julienne Hanson in the 1980s, is a powerful framework for analyzing the spatial configuration of built environments and their impact on social behaviors. This theory proposes that the spatial arrangement of architectural elements can either promote or inhibit social interactions based on the degree of accessibility and connectivity within the space (Hillier and Hanson 1988). Space Syntax is particularly useful for analyzing the flow of movement and the hierarchy of spaces in buildings, providing insights into how these configurations affect social behaviors. Several studies have utilized Space Syntax to investigate the role of architectural design in fostering social dynamics. For instance, Klarqvist (1993) applied Space Syntax to historical buildings to understand how spatial structures mediated social interactions in various cultures. Similarly, Karimi (2012) analyzed how urban configurations shape movement and social behavior, reinforcing the importance of spatial hierarchies in architectural design. Applying this theory to Havelis, with their distinct divisions between public and private spaces, allows for a deeper understanding of how the spatial arrangement of courtyards facilitates or restricts interaction based on social roles. In the context of Havelis, the spatial layout often involves segregated spaces for men and women, with courtyards acting as central points of interaction. The division between public and private spaces within the Havelis reflects the underlying social norms, particularly concerning gender and social hierarchy. Space Syntax Theory enables a detailed analysis of these configurations by quantifying spatial properties such as integration, connectivity, and visibility, offering insights into how these courtyards structured social life within the Havelis.

Gender and Space Theory offers a critical lens through which to examine the relationship between built environments and gender dynamics. Scholars like Platzky and Massey (1995) and Ardener (2021) have highlighted how spaces are often socially constructed in ways that reflect and reinforce gendered power relations. According to Gender and Space Theory, architectural spaces are not neutral; they are embedded with societal norms and values that dictate how men and women can use, move through, and experience them. For instance, Platzky and Massey (1995) argues that the design of spaces can either challenge or reinforce traditional gender roles. In patriarchal societies, spatial segregation—such as separate spaces for men and women—often reinforces the notion of women's subordination by limiting their access to public spaces. This theory is particularly relevant when studying Havelis, where distinct gendered spaces, such as the Zenana (women's quarters) and Mardana (men's quarters), are key features. These spatial arrangements reflect historical practices of gender segregation, designed to protect and control women's activities within the household. Studies by Favro and Weisman (1994) demonstrate how spatial arrangements in homes and public buildings can marginalize or empower women. By applying Gender and Space Theory to the study of Havelis, this research examines how courtyards serve as both physical and symbolic spaces where gender roles are enacted and reinforced.

Environmental psychology focuses on the interaction between individuals and their physical environments, examining how architectural elements influence behavior, well-being, and social interactions. This field of study is particularly relevant in the analysis of courtyards, which serve not only as functional spaces for ventilation and light but also as psychological and social environments that shape the occupants' experiences. Research in environmental psychology has shown that the design of physical spaces can significantly impact human behavior, emotional well-being, and social cohesion. Kaplan and Kaplan (1989) work on restorative environments, for example, highlighted how natural elements in architecture, such as courtyards, can promote mental well-being by providing spaces for relaxation, reflection, and socialization. In the context of Indian Havelis, courtyards often function as microclimatic modifiers, regulating temperature and airflow while also serving as communal spaces for social gatherings and family activities. These spaces have a profound impact on the psychological well-being of their inhabitants, offering a sense of openness, connectivity to nature, and social engagement. Courtyard designs, particularly in vernacular architecture, have been studied for their ability to create thermally comfortable environments that enhance human comfort. Studies by Lozar and Rapoport (1970) and Oliver (2007) have emphasized the importance of culturally appropriate architecture that not only meets functional needs but also aligns with the social and psychological needs of the community. In this study, environmental psychology will be used to examine how the spatial dimensions, light, and ventilation in courtyards affect the occupants' well-being and social interactions. For instance, the height-to-width ratios of courtyards, as discussed by Steemers (2017) can influence both the physical and emotional experience of space, contributing to feelings of openness, privacy, or enclosure.

METHODOLOGY

This study investigates the courtyard designs of four selected Havelis in Rajasthan, focusing on their spatial configurations, environmental responses, and socio-cultural dynamics. The selected Havelis are Mandawa Haveli, Nathmal Ji ki Haveli, Poddar Haveli, and Piramal Haveli, all of which feature two courtyards and are representative of the architectural practices of Western Indian Havelis from the late 19th to early 20th centuries. These courtyards are analyzed using both qualitative and quantitative methods, incorporating data on dimensions, material use, environmental performance, and spatial hierarchies. The rationale behind the selection of these particular havelis is elaborated in the subsequent section.

The analytical framework is structured around three key theoretical lenses—Space Syntax Theory, Gender and Space Theory, and Environmental Psychology—and is supported by specific parameters derived from the literature. These parameters include thermal comfort indices, airflow patterns, daylight factors, and material properties, all of which contribute to a holistic understanding of courtyard design. The spatial configurations of the courtyards are analyzed using Space Syntax Theory to understand how the layout influences social interactions, movement, and privacy. Connectivity is one of the parameters which examines the number of spaces connected to the courtyard, that affects movement and social interaction patterns. Courtyards with higher connectivity facilitate more social interactions and serve as central nodes in the Haveli's spatial organization. Gendered spaces within the Havelis are assessed using Gender and Space Theory, focusing on the segregation of spaces and the role courtyards play in maintaining or challenging gender hierarchies. The parameters for this analysis include 'access control' and 'visibility and privacy'. Access control looks at how access to different courtyards is controlled and segregated by gender. For example, front courtyards are typically associated with male-dominated activities, while back courtyards serve women's private spaces. 'Visibility and privacy' parameter examines the architectural elements that regulate visibility and privacy, such as the use of elevated rooms and latticework, particularly in relation to the Zenana (women's quarters). The environmental performance of the courtyards is evaluated using principles from Environmental Psychology and passive climate control strategies. Key parameters derived from the literature include Thermal Comfort Index, Daylight Factor and Ventilation Efficiency. The thermal comfort within courtyards is assessed by analyzing temperature variations, airflow rates, and shading. Courtyards with a higher length-to-height ratio, such as those in Nathmal Ji ki Haveli, create cooler microclimates by enhancing airflow and shading. Daylight Factor measures the amount of natural light penetrating the courtyards, particularly in relation to the height of surrounding buildings and the openness of the courtyard. Courtyards with lower depth-to-height ratios allow for greater light penetration, enhancing visibility and creating a more open spatial experience. Ventilation Efficiency evaluates how effectively courtyards facilitate passive ventilation. The strategic placement of windows, doors, and openings in the courtyards enhances cross-ventilation, contributing to thermal comfort, particularly in the arid climate of Rajasthan. This research limits the quantitative assessment of these parameters from field survey, rather, focus on understanding of these parameters through available secondary data on architectural plans and sections.

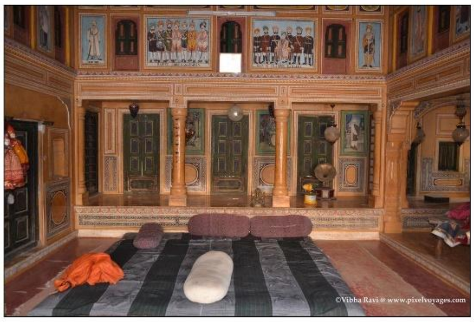
Detailed measurements of courtyard dimensions (length, breadth, height) are collected from secondary sources and by analysis Google Map data. These dimensions are compared to modern building codes, including the National Building Code of India (2016), to assess compliance and deviations. Floor plans and section drawings are used to analyze spatial configurations and connectivity.

By grounding the analysis within established theoretical frameworks and incorporating specific environmental and social parameters derived from the literature, this study provides a comprehensive investigation of courtyard designs in Western Indian Havelis. The integration of thermal comfort indices, airflow rates, and space syntax measures allows for a multidimensional understanding of how these courtyards function both architecturally and socially. This approach also offers insights that can inform future courtyard design in contemporary architecture.

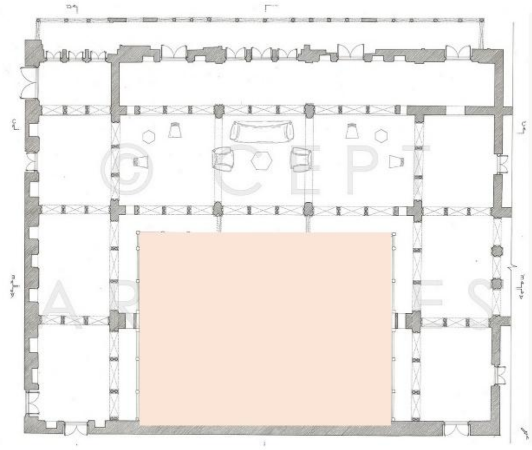
Investigation of courtyards in western Indian havelis

The havelis in western India predominantly date back to the period spanning the 17th century to the early 20th century. To facilitate a comparison with current building guidelines, our case study focuses on recent havelis i.e. constructed in late 19th century to early 20th century. Moreover, to ensure relevance, the selected havelis remain in contemporary use, considering that many havelis in these regions are restricted. In addition to architectural proportions, the environmental responsiveness of Havelis, particularly through the use of courtyards, reflects an adaptive approach to the region's macro and microclimatic conditions. These Havelis, constructed between the 17th and 20th centuries, use courtyards as natural climate moderators, leveraging traditional architectural principles to achieve thermal comfort and efficient ventilation.

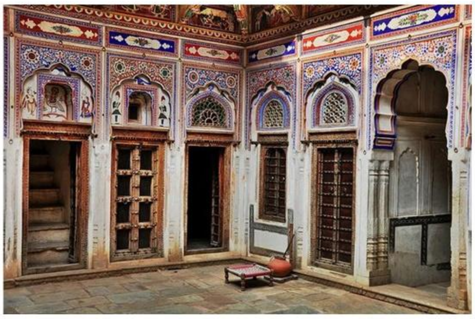
In Rajasthani havelis, residents focus on the navigation of male guests through the ground floor courtyard, leading them into the 'baithak' or public reception room. Noteworthy are the elevated rooms for women situated on either side of the baithak, characterized by low ceilings and arched openings, allowing discreet observation of events. In instances where the guest is a relative, access is granted to private living quarters used by the family, emphasizing the multifaceted use of space within havelis. The presence of one, two, or occasionally multiple courtyards introduces a varied spatial hierarchy (Figure 1). Stairways positioned on two or three sides of the courtyard facilitate access to rooms on the first floor, with a connecting walkway named 'firnee' linking the spaces. The architectural distinction of havelis with two courtyards designates the semi-private forecourt as the 'Mardana' or men's courtyard, while the inner court becomes the 'Zenana' or women's courtyard . Notably, rooms surrounding the inner courtyard serve dual purposes, housing both living spaces and functional areas like kitchens and storage rooms for grains and water. The revelation that, in havelis with a single courtyard, the younger generation typically resides on the first floor while the older generation occupies the ground floor prompts questions about the dynamics of gender segregation in such instances. Further research is warranted to unravel the intricacies of intergenerational spatial allocation and its implications for gendered interactions within the haveli environment. This research limits to focus on double courtyard havelis.



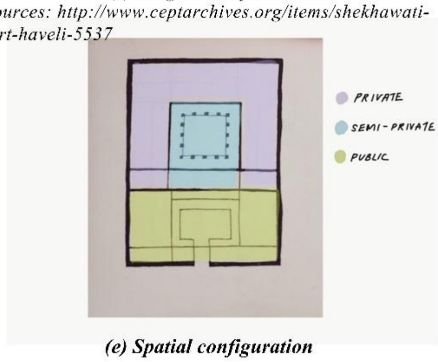
(a) Baithak
Source: https://pixelvoyages.com/2015/12/17/shekhawatis-havelis-an-architectural-perspective-and-brief-travel-guide/



(c) Single courtyard haveli
Sources: http://www.ceptarchives.org/items/shekhawati-fort-haveli-5537



(b) Inner Courtyard
Sources: https://in.pinterest.com/pin/662451426409707629/



(e) Spatial configuration
Source:https://jaipurthrumylens.com/2021/01/06/haveli-shekhawati-region-rajasthan/

Figure 1: Courtyards in Rajasthani Havelis

Considering timeline of construction and contemporary use in these havelis, four two courtyards havelis from western India have been chosen for the case study: Mandawa Haveli in Mandawa, Jhunjhunu, Rajasthan; Nathmal Ji ki Haveli in Sadar Bazar, Jaisalmer, Rajasthan; Poddar Haveli in Naya Bazar, Nawalgarh, Rajasthan; and Piramal's Haveli in Village Bagar, Jhunjhunu District, Chirawa, Baggar, Shekhavati, Rajasthan. This section delves into the historical timelines of construction and distinctive features of these havelis, providing a rationale for their selection as case studies.

Detail insights on selected havelis

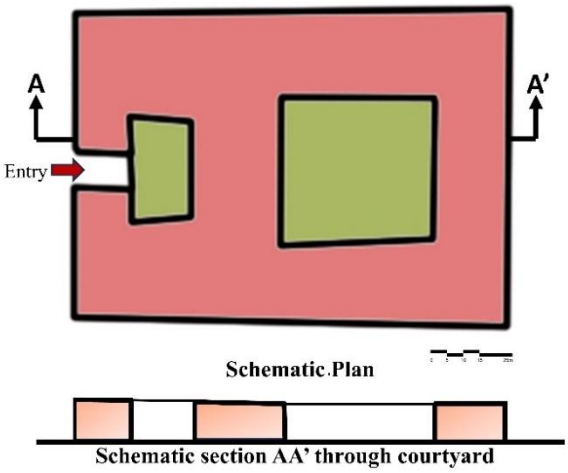
Mandawa haveli

The construction of Thakur Bhagwant Singhji's haveli took place in the late 19th century. Initially serving as the residence of Mandawa's ruler, it has since been transformed into a tourist attraction, welcoming visitors for both sightseeing and accommodations. Situated in the Shekhawati region, the haveli is renowned for its exceptional artistic works and impeccable architectural features. The frescoes, opulent pillars, and various structural elements distinguish this historical site. Adorning the haveli's ceiling are exquisite paintings embellished with jewels, showcasing a rich artistic heritage. Furthermore, the haveli preserves its historical charm through the retention of ancient upholstery and traditional leather Mojadi footwear. This haveli features two courtyards as shown in Figure 2. Similar to the typical two-courtyard havelis in western India, it follows the conventional arrangement of a front courtyard, designated as public, and a larger back courtyard, which serves as the private space.The design of the Mandawa Haveli's courtyards exemplifies passive climate control strategies. The front courtyard, open to the sky, enhances ventilation and provides a cooling effect through convective airflows, particularly important in Rajasthan's arid climate. The back courtyard, slightly larger, plays a more private role, but also functions as a thermal sink. The courtyard’s dimensions, with a height-to-width ratio of 1:3, create a shaded environment for much of the day, mitigating the heat gain. Additionally, the layout supports diurnal temperature variation, allowing cooler night air to circulate through the courtyard and adjacent rooms, reducing the need for active cooling.

Mandawa Haveli's architectural design demonstrates a sophisticated understanding of spatial organization, with its courtyards functioning as key nodes in the spatial hierarchy. Through Space Syntax Theory, the courtyard can be seen as a central space that organizes movement and interaction between the public and private realms. The front courtyard, with its height-to-width ratio of 1:3, serves as an accessible, well-integrated space that encourages social interactions. Its integration value is high, as it connects seamlessly to other rooms and provides easy circulation throughout the Haveli. The back courtyard, slightly more private, offers a cooling microclimate due to its larger size and enclosed nature. Its spatial configuration promotes passive ventilation, creating a cooler environment by allowing air to circulate through the connected spaces.

In terms of gender dynamics, the Mandawa Haveli adheres to traditional social norms, with the front courtyard being predominantly male-dominated (Mardana), while the inner courtyard serves women (Zenana) and private family activities. Access control and visibility are key elements, with elevated women's quarters allowing for observation without intrusion into public spaces.

From an environmental psychology perspective, the courtyard layout enhances thermal comfort and promotes social cohesion. The larger back courtyard acts as a thermal sink, maintaining cooler temperatures throughout the day, while the smaller front courtyard allows for better airflow and lighting. The balanced proportion of these courtyards contributes to a feeling of openness and connection to nature, fostering relaxation and well-being among the inhabitants.



Sources:http://backtovernacular.weebly.com/blog/housing-profile-mandawa-haveli

Figure 2: Mandawa Haveli

Nathmal Ji ki Haveli

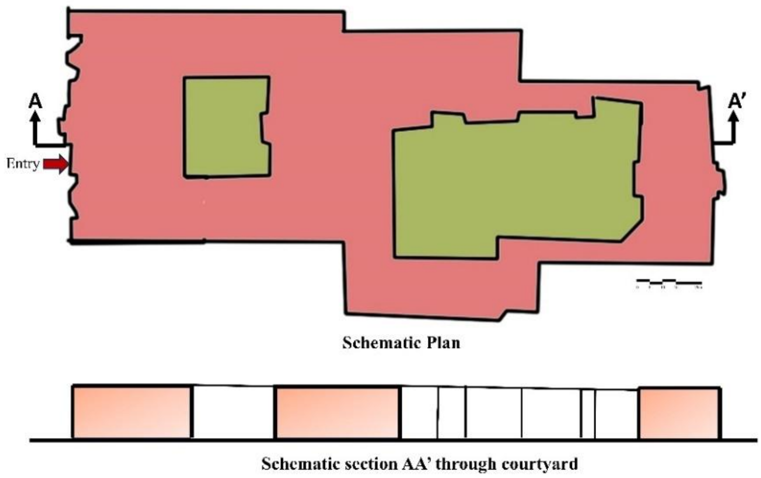
Nathmal Ji ki Haveli stands as a significant tourist destination in Rajasthan, constructed by Maharawal Bairisal, the king of Jaisalmer, towards the end of the 19th century. Interestingly, despite being commissioned by the king, the haveli was inhabited by his prime minister, Mohata Nathmal, leading to its distinctive name. The haveli is renowned for its intricate carvings, lattice works, floral patterns, and other architectural elements reflecting the opulence of royal Rajasthani design. Presently, it serves as a repository of both artifacts and everyday items, providing insight into the lifestyle of the affluent class in ancient times. A discerning observer will notice the haveli's dual architectural styles on each side, a result of a conflict between the two main builders – the prime minister and another architect. This disagreement led to a division of their responsibilities, resulting in the distinct styles evident in the haveli's structure. In this two courtyard haveli, the back courtyard is bigger in size compared to front courtyard like Mandawa Haveli as represented in Figure 3.

Nathmal Ji ki Haveli's architectural layout showcases a nuanced understanding of microclimatic control. The difference in size between the front and back courtyards allows the Haveli to manage sunlight exposure and airflow. The back courtyard's larger expanse captures prevailing breezes, which cool the interior spaces. The intricate latticework and arched windows surrounding the courtyard facilitate controlled air circulation while maintaining privacy. The height-to-length ratio in the back courtyard, at 1:6.5, suggests the creation of an expansive atmosphere while simultaneously using the depth to ensure consistent shading and cooling during the hottest parts of the day.

Nathmal Ji ki Haveli offers a more complex spatial organization, with distinct courtyards reflecting its unique architectural style. The larger back courtyard, with a length-to-height ratio of 1:6.5, introduces a sense of openness and expansiveness, enhancing its connectivity to surrounding spaces. The spatial arrangement here allows for the chimney effect, where cooler air is pulled through the structure, facilitating passive cooling throughout the building. The intricate latticework and arched windows in the back courtyard also improve air circulation while preserving privacy, particularly for the Zenana.

The front courtyard, although smaller, maintains a balanced ratio, facilitating visibility and interaction in the Mardana. The courtyard's design supports the notion of gendered spaces, where men dominate the front areas, and women remain in more secluded sections, emphasizing societal norms around gender segregation. Visibility and privacy play significant roles in maintaining these boundaries, as the courtyard design allows women to observe activities discreetly while remaining out of public view.

From an environmental perspective, the design of the back courtyard provides shade and reduces heat gain, contributing to thermal comfort for the residents. The courtyards also ensure ample daylight without overheating the spaces, enhancing the overall livability of the Haveli.



Sources:https://www.shutterstock.com/search/nathmal-ki-haveli

Sources:https://commons.wikimedia.org/wiki/File:Jaisalmer-Nathmal_ki_Haveli-03-20131010.jpg

Figure. 3: Nathmal Ji ki Haveli

Poddar Haveli

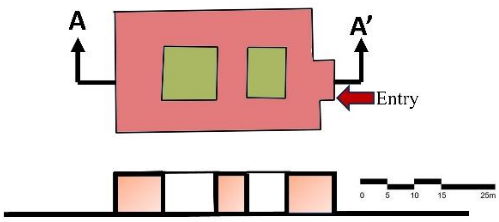
Nestled in the rugged and arid landscapes of Rajasthan, the Anandilal Poddar Haveli stands as a splendid palatial mansion. Mr. Ānandilāl Poddār, a distinguished philanthropist and the founder trustee of the Ānandilāl Poddār Trust, originally constructed the Haveli in 1902 for residential purposes. The Haveli reflects the grandeur and splendor of the Rajput era, making it one of the most captivating tourist places in Rajasthan. The Anandilal Poddar Haveli showcases a rich array of artistic treasures, from beautiful paintings to meticulously crafted murals. It serves as a repository of excellent Rajasthani artwork, embodying the essence of the region's cultural heritage. The Haveli now operates as a museum, divided into various sections, each offering a glimpse into different facets of the Rajput lifestyle and culture. The artifacts on display include musical instruments, kitchen utensils, gems and jewelry, and depictions of festivals, providing a comprehensive exploration of the rich cultural tapestry of Rajasthan. The haveli with two courtyards adheres to the customary arrangement, with the back courtyard being larger than the front courtyard. However, in comparison to other havelis, the size difference is not as substantial as shown in Figure 4.

The Poddar Haveli's courtyards demonstrate a balance between aesthetic and functional considerations. The microclimatic design is reinforced by the compact size of the courtyards, where a length-to-height ratio of 1:1.33 enables rapid heat dissipation in the evenings. The use of materials such as thick stone walls further enhances thermal insulation. These courtyards, particularly the back courtyard, remain shaded for a significant portion of the day, effectively controlling internal temperatures. The smaller dimensions and proximity to living spaces enable the courtyard to act as a communal gathering area while also serving as a natural light well.

Poddar Haveli features a compact yet efficient courtyard design, with the back courtyard having a length-to-height ratio of 1:1.33, providing optimal conditions for natural ventilation and heat dissipation. The integration value of the courtyards is moderate, as the layout is more compartmentalized, serving distinct functions for family activities. The smaller scale of the courtyards facilitates easy movement and interaction, with high connectivity to adjacent living spaces.

In terms of gender dynamics, the back courtyard plays a pivotal role in the private lives of women, while the front courtyard is reserved for public functions and male activities. The architectural layout emphasizes privacy for the Zenana, with restricted access points and limited visibility from public areas, aligning with the principles of Gender and Space Theory.

The environmental performance of Poddar Haveli is enhanced by its thick stone walls and shaded courtyards, which maintain cooler internal temperatures. The compact design ensures efficient use of space while maximizing daylight penetration and cross-ventilation, contributing to both thermal comfort and psychological well-being.



Schematic section A A' through courtyard

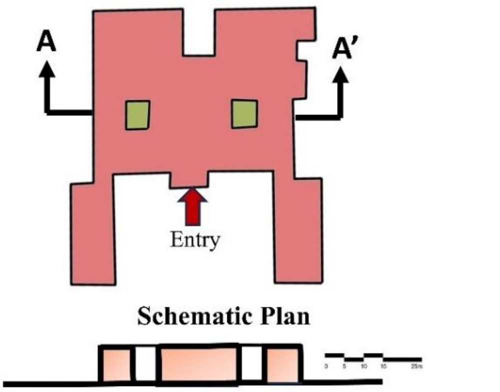
Sources: https://www.justdial.com/Jhunjhunu/Ramnath-Podar-Haveli-Museum-Nawalgarh-Ho/9999P1594-1594-131004152042-T5Y2_BZDET

Figure. 4: Poddar Haveli

Pirmals Haveli

The Piramal Haveli in Baggar stands as an architectural marvel, blending Rajasthani and Italianate influences into a visually stunning structure. Constructed in 1928, this heritage gem is located approximately 40 kilometers away from other hotels in Rajasthan. Commissioned during a period of cultural and artistic flourishing, the haveli was a testament to the opulence and grandeur of the era. Despite its smaller size, the Piramal Haveli served as a residence that encapsulated the lifestyle of the affluent class in the Baggar region. The haveli's design is characterized by its modest yet captivating size, featuring a large open garden and two pillared courtyards. One of the most striking elements of the Piramal Haveli is its intricately adorned frescoes. The pillared courtyards are painted with colorfully kitsch depictions, showcasing a unique blend of motifs that include flying angels, airplanes, and gods in motor cars. These frescoes not only reflect the artistic sensibilities of the time but also add a whimsical and distinctive charm to the haveli. The restoration of the Piramal Haveli has been a meticulous process aimed at preserving its unique architectural features and historical significance. Today, this heritage site offers visitors a glimpse into the past, showcasing the fusion of Rajasthani and Italianate styles, making it stand out as a distinguished cultural and architectural landmark in the Shekhavati region. This haveli boasts two courtyards, each of almost equal size as shown in Figure 5. Notably distinct from other havelis, it lacks a traditional front and back courtyard arrangement, as the entrance is situated in the central space shared by both courtyards.

The Piramal Haveli employs a dual-courtyard design to handle varying degrees of public and private exposure. The nearly symmetrical courtyards (1:1.6 ratio for the front and back) not only serve as gathering spaces but also manage airflow and cooling. The pillars surrounding the courtyards offer structural stability while simultaneously allowing air to circulate freely through the open spaces. The design reflects an understanding of the microclimate by balancing shade with light penetration, creating a thermally comfortable environment.



Schematic section A A' through courtyard

Sources: https://www.tripsavvy.com/shekhawati-rajasthan-travel-guide-1539655

Figure. 5: Pirmals Haveli

The Piramal Haveli, with its dual courtyard design, showcases a near-perfect balance between public and private spaces. Both courtyards maintain a length-to-height ratio of 1:1.6, promoting a sense of symmetry and openness. The connectivity between these courtyards is high, allowing for seamless movement throughout the Haveli and facilitating social interaction. The symmetrical layout of the courtyards suggests a high integration value, where both spaces are equally accessible and central to the building's design.

The gendered division of space is less pronounced in Piramal Haveli, with both courtyards serving communal functions, suggesting a more fluid interpretation of Gender and Space Theory. The courtyards support public gatherings as well as private family activities, reflecting a more modern approach to gender roles.

The environmental design of Piramal Haveli is highly effective in creating a comfortable living environment. The symmetrical courtyards provide ample cross-ventilation, while the use of pillars ensures that air circulates freely through the spaces. The design minimizes heat gain while maximizing daylight penetration, contributing to the overall psychological comfort of the inhabitants.

Comparative analysis and discussion

The comparative analysis of the selected Havelis reveals the complex relationship between courtyard dimensions and the climatic performance of these spaces. While the ratios of length, breadth, and height provide an initial understanding of spatial organization, additional parameters such as solar exposure, ventilation efficiency, and material choices play crucial roles in shaping the microclimate of these courtyards.In the architectural analysis of Nathmal Ji ki Haveli, a distinct pattern emerges in the courtyard dimensions. The front courtyard is characterized by a harmonious and balanced length-to-height ratio, contributing to an aesthetically pleasing design. Conversely, the back courtyard deviates from this equilibrium, displaying a longer length-to-height ratio that imparts a sense of expansiveness. This deliberate contrast underscores the dual functionality of the courtyards, with the front courtyard serving as a visually appealing space and the back courtyard emphasizing a spacious and open ambiance.

Moving on to Mandawa Haveli, a different architectural approach is observed. Both front and back courtyards exhibit proportionate length-to-height ratios, indicating a commitment to symmetry and balance in design. However, the subtle elongation of the back courtyard implies a strategic emphasis on creating a more extended spatial experience. Notably, the front courtyard distinguishes itself by possessing a higher length-to-breadth ratio, contributing to a unique and distinctive layout.

Poddār Haveli further showcases nuanced courtyard design. The front courtyard maintains a commendable equilibrium in its length-to-height ratio, embodying a thoughtful architectural composition. In contrast, the back courtyard extends slightly beyond this balance, featuring a longer length-to-height ratio that introduces a sense of elongation. Simultaneously, the length-to-breadth ratio remains proportionate in both courtyards, contributing to a cohesive and well-integrated design scheme.

Piramals Haveli, in its architectural presentation, echoes a commitment to balanced proportions. Both front and back courtyards exhibit relatively similar and well-matched ratios, presenting a harmonious spatial arrangement. While a subtle difference in the length-to-breadth ratio is noted in the back courtyard, the overall design maintains consistency and coherence.

In summary, the assessment of these havelis underscores the diversity in courtyard dimensions and design philosophies. Front courtyards commonly maintain a balanced length-to-height ratio ranging between 1.3 to 3, contributing to an aesthetically pleasing atmosphere as shown in Table 1. Conversely, back courtyards often deviate with longer length-to-height ratios 1.6 to 6.5, emphasizing spaciousness. The length-to-breadth ratios introduce an additional layer of diversity, with some havelis prioritizing higher ratios in the front courtyard for distinctiveness like Mandawa Haveli (4.2), while others maintain proportionate ratios for a more cohesive design like Poddār Haveli (1.33), Piramals Haveli (1.2).

The Havelis of Western India, situated in a region known for its harsh summers and significant temperature fluctuations, rely on courtyards as thermal moderators. At a macro scale, the orientation of these Havelis optimizes the capture of prevailing breezes while minimizing solar heat gain. For example, the courtyards often face north or are strategically shaded by surrounding walls and trees, protecting the interiors from direct sunlight. At a micro level, the depth of the courtyards and the materials used in construction contribute significantly to their thermal performance. Courtyards with higher walls, such as those in Nathmal Ji ki Haveli, create a chimney effect, pulling cooler air upwards through the building and providing passive cooling. This effect is enhanced by the thick stone walls, which store heat during the day and release it slowly at night, maintaining comfortable indoor temperatures.

The National Building Code of 2016 (NBC 2016) stipulates that the minimum width of the inner courtyard should be 3 m, while the minimum width of the outer courtyard should not be less than 2.4 m. If the width of the outer courtyard falls below 2.4 m, it is categorized as a notch, and the provisions of outer courtyard standards do not apply. Notably, the guidelines in the National Building Code lack specific recommendations regarding courtyard heights, a crucial aspect influencing the quality of a space.

Considering the significance of height in determining the spatial quality, the insights gained from examining the relationships between length, breadth, and height in western havelis become particularly pertinent. Western havelis are renowned for their exceptional spatial quality and the diverse activities conducted within their courtyards. This understanding not only contributes valuable insights to architectural analysis but also establishes a foundation for shaping future courtyard designs. By bridging the gap in existing guidelines and incorporating insights from haveli architecture, architects and designers can enhance the quality and functionality of contemporary courtyards in line with established cultural and architectural practices.

Table 1: Comparative Assessments of courtyards in havelis

	Front Courtyard			**Back Courtyard**		
	Length: Height (Ratio)	**Breadth: Height (Ratio)**	**Length: Breadth (Ratio)**	**Length: Height (Ratio)**	**Breadth: Height (Ratio)**	**Length: Breadth (Ratio)**
Nathmal Ji ki Haveli	2.8	2.5	1.13	6.5	4.2	1.6
Mandawa Haveli	3	2	1.5	4.5	4	1.125
Poddār Haveli	1.33	1	1.33	1.6	1.33	1.2
Pirmals Haveli	1.6	1.2	1.3	1.6	1.2	1.3

Space Syntax Theory reveals that the integration and connectivity of these courtyards vary significantly based on their functional requirements and social contexts. For example, the Mandawa and Nathmal Ji ki Havelis demonstrate a clear hierarchical division between front and back courtyards, with the front courtyard being more integrated into the public sphere, while the back courtyard remains private and secluded. This spatial arrangement reflects the traditional social structures in place, where gender and status dictate the use and accessibility of different spaces.

In contrast, Piramal Haveli presents a more egalitarian layout, with both courtyards being equally accessible and central to the building's organization, suggesting a shift in social norms and a more flexible interpretation of gender roles. Gender and Space Theory emphasizes how the spatial arrangements in the Havelis either reinforce or challenge traditional gender dynamics, with the Mandawa and Nathmal Ji ki Havelis adhering more closely to patriarchal norms, while Piramal Haveli demonstrates a more progressive approach.

From an environmental psychology perspective, the Havelis' courtyards play a crucial role in creating thermally comfortable environments. The size and orientation of the courtyards, combined with material choices and passive climate control strategies, contribute to the overall thermal comfort and psychological well-being of the inhabitants. Courtyards with larger height-to-width ratios, such as those in Nathmal Ji ki Haveli, provide better ventilation and shading, while those in Mandawa Haveli support a balanced microclimate by promoting natural airflow and reducing heat gain.

Discussion of spatial, gendered, and environmental aspects of courtyard architecture

The investigation of the four selected Havelis—Mandawa, Nathmal Ji ki, Poddar, and Piramal's Havelis—through the lens of Space Syntax Theory, Gender and Space Theory, and Environmental Psychology reveals nuanced insights into the role of courtyards in shaping social, spatial, and psychological dynamics. Each theoretical framework helps uncover distinct layers of meaning embedded in the architectural designs, highlighting how these spaces are more than just functional but also deeply rooted in cultural, social, and environmental contexts.

Space Syntax Theory enables us to analyze the spatial configurations of these courtyards and how they govern movement, visibility, and social interactions. In each of the Havelis, the courtyard serves as a central node that organizes the circulation between public and private spaces. For example, the Mandawa Haveli's layout, with its proportionate length-to-height ratios in both front and back courtyards, creates a balanced spatial hierarchy that allows fluid transitions between private and public domains. The placement of stairways on two or three sides of the courtyard in many of these Havelis facilitates vertical circulation, enabling the spatial integration of different floors while maintaining the privacy of various areas, such as the Zenana (women's quarters). In contrast, the Nathmal Ji ki Haveli's asymmetrical courtyard dimensions reflect a deliberate distinction between front and back courtyards, emphasizing the duality of functionality. The back courtyard, with its elongated length-to-height ratio, provides a more secluded and expansive space, suitable for private family activities. This spatial segregation mirrors the underlying social norms, particularly regarding gender and hierarchy, where the public front courtyard is more accessible, while the private back courtyard is reserved for family use. Space Syntax Theory highlights how these spatial divisions regulate social interactions and reinforce social structures within the household.

Gender and Space Theory provides critical insights into how the design of these courtyards reflects and reinforces gender roles. The architectural arrangements in these Havelis reveal a clear demarcation between male and female spaces. For instance, the presence of separate courtyards for men (Mardana) and women (Zenana) in the Mandawa and Nathmal Ji ki Havelis underscores the patriarchal norms that dictated spatial use in these traditional homes. Women were often confined to more private, enclosed spaces, with limited visibility and access to the public sphere, while men dominated the larger, more open courtyards intended for public gatherings and social functions. This spatial segregation is further accentuated in the architectural features of the courtyards. Elevated rooms for women with low ceilings and arched openings, such as those seen in the Nathmal Ji ki Haveli, allowed women to observe public activities discreetly without being seen, reinforcing the social boundaries imposed on their mobility and visibility. Gender and Space Theory helps us understand how these architectural choices were not merely functional but symbolic of the broader societal expectations and restrictions placed on women's roles and behaviors within the household.

From an environmental psychology perspective, the courtyard designs in these Havelis play a crucial role in enhancing the psychological well-being and social cohesion of their inhabitants. The courtyards act as microclimatic modifiers, regulating temperature and airflow, making them comfortable spaces for communal activities. For example, the height-to-width ratios of the courtyards in the Mandawa Haveli contribute to a sense of openness and connection to nature, which is psychologically beneficial, providing spaces for relaxation, socialization, and family gatherings. Moreover, the intricate frescoes and ornamental designs in the Piramal Haveli's courtyards, which blend Rajasthani and Italianate styles, add aesthetic value that enhances the occupants' emotional experiences within these spaces. The interplay of natural light, ventilation, and visual elements in these courtyards creates a serene and aesthetically pleasing environment, contributing to both physical comfort and psychological well-being. As Environmental Psychology suggests, these architectural elements foster a sense of belonging and social engagement, while also providing a space for reflection and personal well-being.

By examining these courtyards through the lenses of Space Syntax Theory, Gender and Space Theory, and Environmental Psychology, it becomes clear that the architectural design of courtyards in Western Indian Havelis is intricately tied to the social, cultural, and psychological dimensions of their inhabitants. The spatial configurations influence social interactions, while the gendered use of space reflects broader societal norms. At the same time, the environmental qualities of these courtyards promote comfort and well-being, underscoring their enduring significance in both historical and contemporary contexts.

CONCLUSION

This study sheds light on the intricate and multi-facete role of courtyards in Western Indian Havelis, focusing on their spatial, social, and environmental dimensions. The investigation of four two-courtyard Havelis—Mandawa, Nathmal Ji ki, Poddar, and Piramal Havelis—demonstrates the rich interplay between architectural design, cultural practices, and climatic adaptation. By employing theoretical frameworks such as Space Syntax Theory, Gender and Space Theory, and Environmental Psychology, the study uncovers new insights into how these courtyards not only serve functional purposes but also shape social interactions, enforce or challenge gender norms, and contribute to the psychological well-being of their inhabitants.

From a spatial perspective, Space Syntax Theory reveals how the design of these courtyards creates a clear hierarchy of spaces, facilitating movement and interaction while maintaining privacy. In particular, the higher integration values of front courtyards reflect their public nature, while back courtyards are more secluded, supporting family and gendered dynamics. The Gender and Space Theory analysis emphasizes the spatial segregation of male and female spaces, with architectural elements such as elevated rooms and latticework playing key roles in maintaining these social boundaries. The design of courtyards reinforces patriarchal structures in some Havelis, while others, like Piramal Haveli, reflect more fluid gender roles.

From an environmental standpoint, the courtyards of these Havelis function as passive climate control systems, significantly enhancing the thermal comfort of residents. Through Environmental Psychology, the study shows how courtyard proportions and spatial arrangements—particularly in relation to ventilation, shading, and daylight—contribute to a balanced microclimate, providing comfortable living environments in Rajasthan's harsh climate. Courtyards with higher length-to-height ratios, such as those in Nathmal Ji ki Haveli, facilitate natural cooling through enhanced airflow, while compact designs, like those in Poddar Haveli, ensure thermal efficiency and effective use of space.

In addition to providing a comprehensive analysis of the spatial and environmental functions of courtyards, this study highlights the absence of specific guidelines on courtyard heights in the National Building Code of India (2016). The findings suggest that incorporating detailed recommendations for courtyard dimensions, particularly height, could improve the design of modern courtyards, allowing them to better respond to both cultural and environmental needs.

Overall, this research deepens our understanding of courtyard designs in Western Indian Havelis, offering valuable lessons for contemporary architecture. By bridging the gap between traditional practices and modern requirements, architects and urban planners can draw inspiration from these findings to create spaces that are not only environmentally efficient but also socially responsive. Future research could further explore the quantitative assessment of environmental performance through primary data collection and apply these insights to other forms of vernacular architecture across India. .

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Exploring Cultural Identity in the Old City of Gwalior through Place, Memory and Community

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Abstract— Medieval towns were not built in a day; they encompassed many layers of memories. Historic towns and cities exhibit patterns that reflect their culture, planning, and landscape. These towns harbor numerous associated memories reflected in their planning, culture, traditions, emotions, and community organization. This means on a broader scale, the city itself carries cultural-social memory that is also visible on a micro level in the old town, is meticulously organized, and reflects societal hierarchies, fostering a unique communal identity within distinct boundaries that should be explored. It's also seen gentrification takes place in such places, but the fundamental character of streets, built forms, and public spaces caters to enduring memories. Cultural influences persist through generations, evolving into an essential facet of the community. Despite transformations over time, a distinct identity endures in the streets, public spaces, and architectural styles, notably exemplified in the historic city of Old Gwalior. This city reflects a transformation from Rajput, Mughal and Maratha to Colonial architecture, showcasing the contributions of the community, thereby imparting a unique architectural style and identity to the city. The old town of Gwalior encompasses essential elements and numerous memories. This paper explores such places and their associated memories, which give identity to the town. The focus is on specific areas that delve into culture, identity, place, and memory. As suggested by Kevin Lynch, the legibility and imageability of cities incorporate memory in defining them. This study identifies streets and precincts brimming with cultural vibrancy, influencing both architecture and the city's essence based on the survey.

Keywords: Culture; Identity of Place; Memory; Urban Character

INTRODUCTION

Old Gwalior, nestled in Madhya Pradesh, has held immense political and cultural significance since medieval times, ruled by diverse dynasties such as Pratihars, Tomar, Lodhi, Mughals, Marathas and Britishers. Attesting to its grandeur, the city houses a magnificent fort due to its size and strategic positioning. The old city of Gwalior spanning about 2.5 square kilometers extends from the Swarna Rekha River in the east to Ladheri Hill in the north and Sagar Tal in the west. The study also reveals a broader perspective of the entire city that holds a collective memory that is embodied in its cultural landscape, which is gradually fading due to urbanization and colonization. These memories manifest in various forms such as tangible and intangible respectively like rivers, mountains, graveyards, religious structures, water bodies, gateways, rituals, belonging, oral traditions and beliefs that are found in the study.

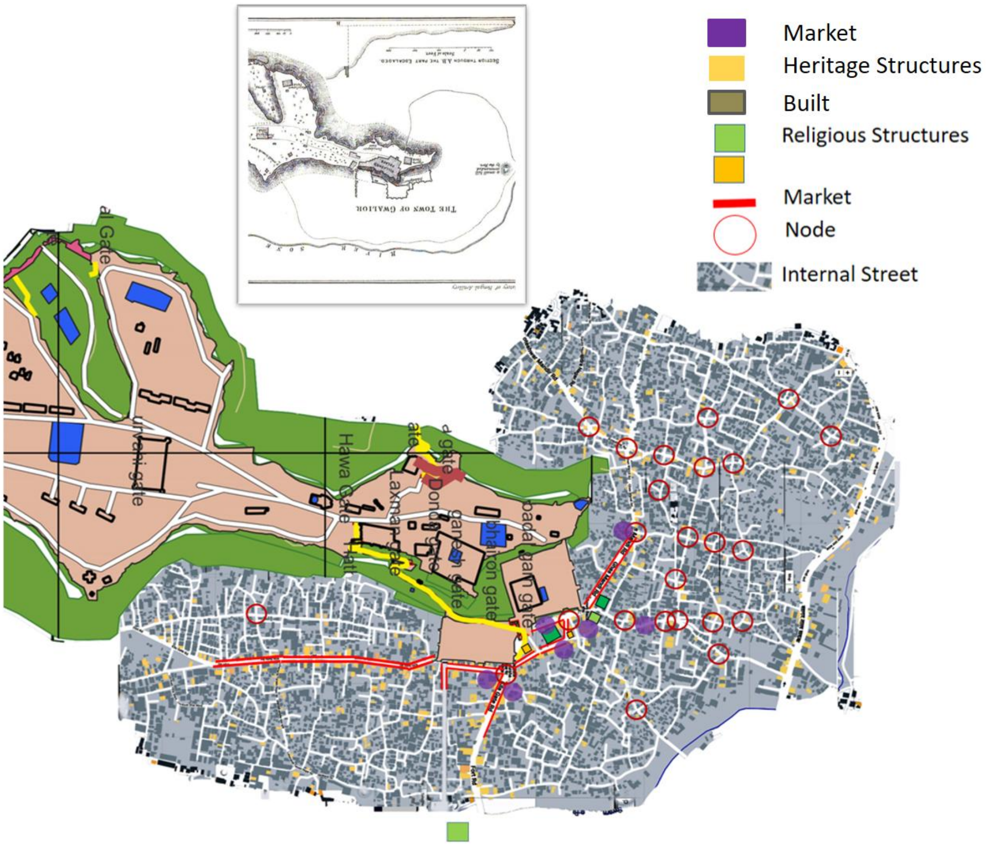


Figure 1 Old Gwalior Sprawl of 1780's boundary superimposed on current satellite map showing attributes.

Reference: History of Bengal artillery Map(inset), Author

LITERATURE REVIEW

The study gave insight that memory plays a crucial role in connecting with a place and its people and beyond. So, the literature reviewed in this research paper explores the intricate connections between memory, urban spaces, architecture and the cultural identity of the city. Further to reading the old city, it suggests that the study takes into account the concept of "imageability," as explained by Kevin Lynch. Imageability refers to how easily a place can be formed into a mental image. The study highlights the importance of imageability in assessing environmental quality and notes a positive correlation between how well a place is mentally navigated (Mind Mapping) and how it is utilized and perceived as believed by (Ford, 1999) which indicates the sources supporting these ideas (Lindsay J. McCunn, 2017).

The Mental maps, which are representations of one's cognitive perception of a place, are repositories of accumulated memories. This delves into the exploration of memorialization and commemorative structures. These structures are considered creative expressions that seek to connect future generations with moral lessons and historical truths by transforming memories into architectural forms. The citation (Allen, 2009) likely supports the idea that such structures aim to honor past sacrifices. However, challenges emerge when these structures are displaced due to urban development. This displacement can lead to the creation of false memories, even as the original associated memories continue to persist.

It also shows that rituals play a significant role in influencing urban structure, sustaining collective memory, nurturing attachment, and shaping the overall urban imagery. The citation (Krishnamurthy, Rituals and the participation of urban form: Informal and formal image making processes, 2015) likely discusses the impact of rituals on urban dynamics. Rituals are described as recurring social events that re-enact myths and revive memories associated with various elements such as events, places, or individuals. The references to Kanekar (1992), Connerton (1989), Koster (2003), and Rossi (1984) imply that these scholars contribute to the understanding of how rituals contribute to cultural and social continuity, infusing urban spaces with commemorative value mentioned by (Krishnamurthy, Rituals and the participation of urban form: Informal and formal image making processes, 2015, p. 7).

Further study explores the concept of "Living Archaeology of the Place," with a specific focus on traditions, day-to-day rituals, urban life, and personal cultural identities. These elements are considered integral components of collective cultural memory, as discussed by (Terracciano, 2017, p. 18) additionally, the review underscores the significant relationship between memory and identity, asserting that one's identity within a social group is shaped by memory. This assertion is attributed by (Mussi, Pinheiro, Soca, & Biachin, 2022).

The study highlights intangible cultural assets within bazaars, which reflect a culture's skills, values, customs, and beliefs. It is also seen in the study of the organic city's neighbourhoods are characterized by names reflecting economic activities, and streets are considered vital elements with unique identities that hold meaning in people's lives, the insight is attributed by (Rajgopal, 2008) and (Meeta Tandonn, 2017).

The unique aspect of reading the city through the senses is introduced, as suggested by (Terracciano, 2017). This sensory approach helps create a mental environment, conceptualized as memory boxes with diverse architectural shapes and digital sensory elements that capture the essence of places. The engagement with these sensory spaces is said to encourage exploration of the interplay between bodies, memories, and urban settings, facilitating an expressive form of art and allowing immersion in the living history of cities (Terracciano, 2017, p. 18).

As also mentioned in the Archaeologies of the Greek past Landscape, Monuments & Memories "Social memory is manifestly a mighty force, but also a fugitive one. Memories overlap and compete; over time they change or are eradicated; people forget" (Alcock, 2002, p. 1). This suggests that social memory is a powerful and impactful force within a society, yet it is also transient and elusive. Memories within a social context tend to intersect, contend with each other, undergo changes or even disappear over time, and individuals may forget them. For example, historical events or cultural practices that were once widely remembered and celebrated may gradually fade from collective memory, especially as generations change or societal values evolve.

METHODOLOGY:

To comprehend Gwalior's cultural identity, archival maps were gathered to understand the city's land usage and sprawl. Through visual surveys, structural typologies, town sprawl, access networks, natural features and natural defensive boundaries were identified. These findings were then mapped on a QGIS survey were conducted to locate the place, identity and community. The study emphasized the influence of architecture on the city's planning and communities. For a more in-depth examination, interviews and surveys were conducted within the precinct of Shahi Jama Masjid, providing a micro-level study to capture memory, identity and sense of place. From the reference of 1780 General Popham map shown in Figure 1 were taken into consideration which indicates the urban expansion of the old town and gives inferences for delineating the study area. This map serves as a crucial milestone in understanding the city's cultural landscape, shedding light on old routes, religious sites, water bodies, cremation grounds, and burial sites, while some endure, others have faded from memory, losing their distinctive identities. To comprehend the old city, a broader perspective has been examined from the perspective of the historical urban landscape which encompassing the town's functioning on a broader scale which serves as a collective memory. The old town's essence from the perspectives of its people and historical maps, sought to bridge the gap between its present and past, intricately linked through memory. This approach facilitated a comprehensive analysis of the context, community, and identity of the places. The research employed a combination of primary and secondary data collection methods. Primary data involved conducting semi-structured, in-depth interviews using a community participatory approach to gather narratives, extract specific qualitative insights, and prepare a mind mapping of the Old City.

Exploring Old Gwalior: Landmarks, Memory, and Identity through Surveys

Surveys were conducted in two groups to understand Old Gwalior, aiding in comprehending the city's landmarks, collective memory, and identity. The first survey targeted individuals from Lashkar, Morar, and another survey from the neighbourhood itself. Seeking insights into the old market, neighbourhoods, landmarks, and the historical aspects of Gwalior. The second survey specifically focused on residents of Old Gwalior, aiming to capture memories associated with the Old Gwalior. The selection of questions and respondents was based on their connection and emotional attachment to old Gwalior. The survey results are detailed below. The survey revealed that 50% of Gwalior (other than Old Gwalior) residents, having lived there for over 30 years, have not ventured beyond the fort to explore

Old Gwalior and its surrounding Neighbourhoods. This provided significant insights into perceptions of Old Gwalior (Figure 2). The language of the survey was in Hindi so the respondent could answer correctly after understanding the questions. This study, involving adult men and women, youngsters, and senior citizens, did not consider gender or occupation in its assessment. Questions were posed to the residents and after sites were explored visually to map the places and correlate with the mental image.

Exploring Place Identity in Old Gwalior: Streets, Memories, and Imageability

The study underscores the highly individualized nature of perceptions related to place association and identity, emphasizing the pivotal role played by individual perspectives in shaping a place's identity. In the context of Old Gwalior towns the streets, serving as primary, secondary, and tertiary thoroughfares, exhibit diverse characteristics that contribute to the city's social fabric. These streets, like Lakhera Gali, Sunaron ki Gali, Sayeedon ka Mohalla, Halwat Khana, and Kashi Naresh ki Gali, possess distinct identities and memories associated with these streets, relying on landmarks, colour palettes, streetscape elements and sense of enclosure significantly aid in their identification.

During interviews with neighbourhood residents aged 15 to 45, photographs of streets and landmarks prompted individuals to readily identify locations, drawing upon their memories intertwined with personal connections to the street and its surroundings. However, close-up images of features like hand pumps, baoris, or dalans posed recognition challenges, suggesting varying impacts on individuals. Engaging in movement-based interviews and first-hand experiences, the study crafted a memory map delineating the identity and memories of Old Gwalior as shown in Figure 2 which shows the broader Historic Landscape of the city which encompasses many memories in the form of water bodies, crematory ground, religious structures, Commemorative structures, Baghs, River further from Lynch's concept of imageability which focusing on shapes, colours or arrangements that create vivid mental images of the environment, was explored and found the character in Lakhera Gali,Ladheri settlement. Elderly individuals exhibited proficient navigation in urban areas, guided by their thorough familiarity with the city's cultural surroundings.

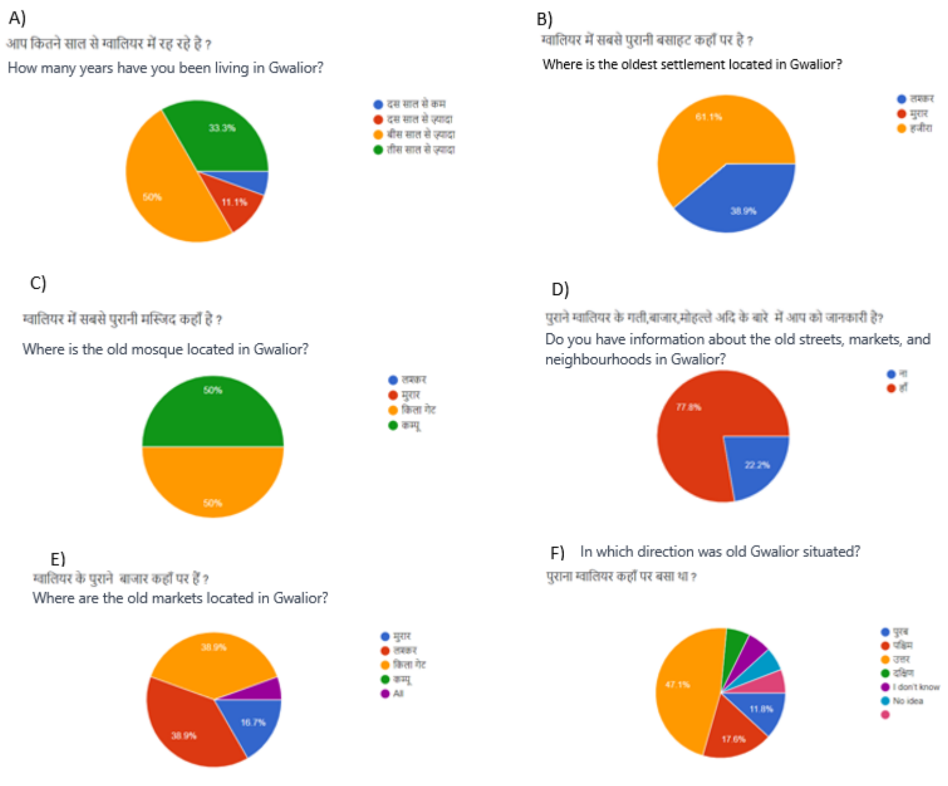
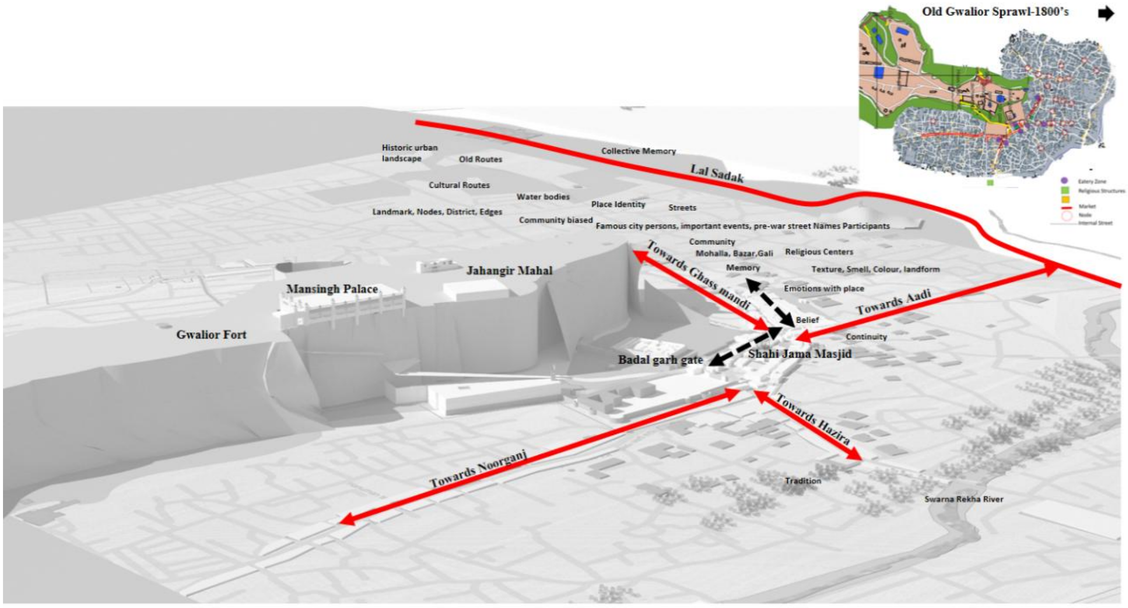


Figure 2 Responses from the Survey for the study of old Gwalior

New landmarks, existing for over a decade, like the Atta Chakki , tailor shops, cycle repair shops, dairy farms, public toilets (identified by odour), schools (sound) and Dharamshala became ingrained in local memory and were associated with the place. However, newly established ventures within the old precinct may not be universally recognized by all residents. The mental map, resulting from a citywide survey and interviews, illustrates spatial connections and possesses specific map-like qualities easily interpretable through textual descriptions and illustrations. Formulated to comprehend and communicate the city's essence and imageability, the mental map is grounded in people's memories observed within the historical urban landscape, providing a broader perspective on memory within the research context.

Figure 3 Showing emotions of collective memory of Old Gwalior.

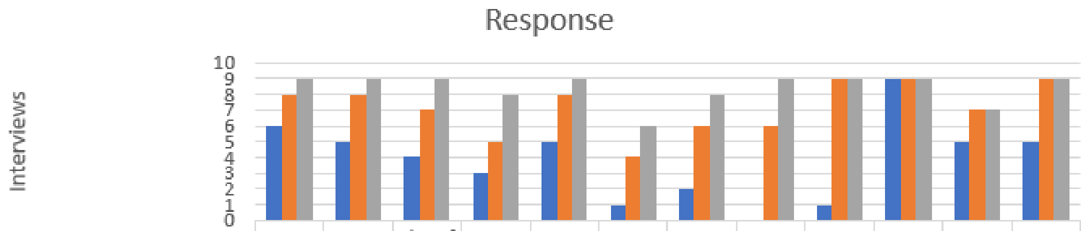


Perceptions and Identities: Unveiling the Unique Character of Old Gwalior through memories

This underscores the individualized nature of perceptions regarding place association and identity, particularly within the context of old Indian towns like Old Gwalior. Streets in these towns serve diverse functions, acting as primary, secondary, and tertiary thoroughfares for travel and social activities. These streets, characterized by unique features and community planning, form the vital arteries of the city, each possessing a distinct identity shaped by architecture, land availability, and community characteristics. During interviews with residents, memories linked to specific streets were crucial in their identification like relying on distinct landmarks, colour palettes, streetscape elements, and other defining attributes (Figure 4). However, close-up images of certain features posed recognition challenges, suggesting that some elements lacked strong associations.

The study utilized movement-based interviews and first hand experiences to craft a memory map, delineating the identity and memories of Old Gwalior. The concept of "imageability," as defined by Lynch is mentioned in Spatial navigation and place imageability in sense of place (Lindsay J. McCunn, 2017)emphasizing its role in creating vivid mental images of the environment. The passage notes the significance of elderly individuals' familiarity with directional cues and their ability to navigate urban spaces this helps in preparing a mental map of the old city which is later illustrated in Figure 5.

New landmarks, both existing and newly established, contribute to the locals' memory, with some establishments becoming ingrained over a decade. The mental map created after a citywide survey and interviews illustrate spatial connections with map-like features, easily interpreted through textual descriptions and illustrations. Overall, this approach provides a comprehensive understanding of the city's essence and imageability, grounded in the collective memories observed within the historical urban landscape.



	Identify the location from the photograph.	Identify of a Place	Identify a familiar location based on the direc...	Familiar landmark in the vicinity of the street.	Culinary places of Old Gwalior	Familiar with the city's cultural layout	Can place associate with the festive ?	Knows the Graveyards and Madristan	Recognise Tansen Talkies	Watch a glimpse of the fort once a day .	Recognize the city with soundscape	Recognize the time through the sound of Religious...
Above 15 years of age	6	5	4	3	5	1	2	0	1	9	5	5
Above 45 years of age	8	8	7	5	8	4	6	6	9	9	7	9
Above 60 years of age	9	9	9	8	9	6	8	9	9	9	7	9

Figure 4 Mind Mapping of Old Gwalior on the basis of field Survey and Interviews from the locals.

Visual surveys uncovered a range of religious edifices in Gwalior, encompassing Hindu, Muslim, and Jain places of worship. Prominent among these structures is the Shahi Jama Masjid, surrounded by both Muslim and Hindu communities. The city's settlement pattern reveals an Islamic influence, mirroring its historical development. Despite the presence of Muslim religious sites, a spirit of Sufi vibes thrived, particularly during the Mughal and Maratha rule. Gwalior's old city, marked by its intricate layers of construction, mirrors a tapestry of cultural richness, architectural diversity and oral traditions. The tradition of venerating Sayeed Baba 'Aalla' persists in local households, fostering a sense of continuity and belonging to the region and belief.

Figure 5 Mental Map of Old Gwalior: Surveying the locals in the study area to discern their memories, attachments, and perceptions of the region.

Islamic Architecture and Culinary Traditions: A Glimpse into Old Gwalior's Identity

The vicinity of the Gwalior Fort retains numerous memories that are associated with the neighbourhood, Table 1 Shows identified neighbourhoods and structures associated with the memory in tangible and intangible forms such as built structures, planning and culture. It is also observed that during the time gentrification has done but the traces of cultural value, traditions and a sense of belonging persist in the old city. Thus, Old Gwalior remains a repository of collective memory, preserving its rich heritage.

The urban planning of Old Gwalior is intricately tied to the fort and trade routes, influenced by various rulers. A significant transformation occurred in the 16th century with the construction of religious structures, leading to a shift in the town's axis. This period witnessed the flourishing of markets and community-based neighbourhoods, marked by distinctive architectural styles and later in 18th century brought about major changes with the settlement of Kashi Naresh , leading to the development of new markets and neighbourhoods like Anaj Mandi, Kashi Naresh ki Gali, Rangania Mohalla, and Rani ka Pura. The town underwent a rich cultural transformation encompassing historic structures, cuisines, traditions, beliefs and a sense of belonging. The study delves into sensory exploration, identifying places where prayers and bhajans resonate through sound, the fragrance of cuisines during Gazak preparation, and the tactile experience of architectural building materials. The surrounding area accommodates Figure 6 residences of both Hindus and Muslims, continuing a tradition where each household possesses an 'Aala ,' attributed to Sayeed Baba, for worship, prayer, and offering sheera —a practice passed down through generations. Culinary connections to the area include traditional market shops around the Shahi Jama Masjid, specializing in ropes, baskets, and Gazak , a Mughal delicacy. The link to Gazak reflects Mughal culinary practices, becoming an integral part of the area's identity. Additionally, several small-scale industries have established themselves, further intertwining the locale's identity with its culinary practices and historical significance. Halwat Khana , associated with Islamic stories and magic, contributes to the local memory, with similar stories found in other sites like the Temples of Pietra (TANEJA, 2013)mention of Jinnealogy in post-partition Delhi and the association of Islamic graves in Old Delhi with Jinn miracles and magic align with stories from Arab countries (Ford, 2023).

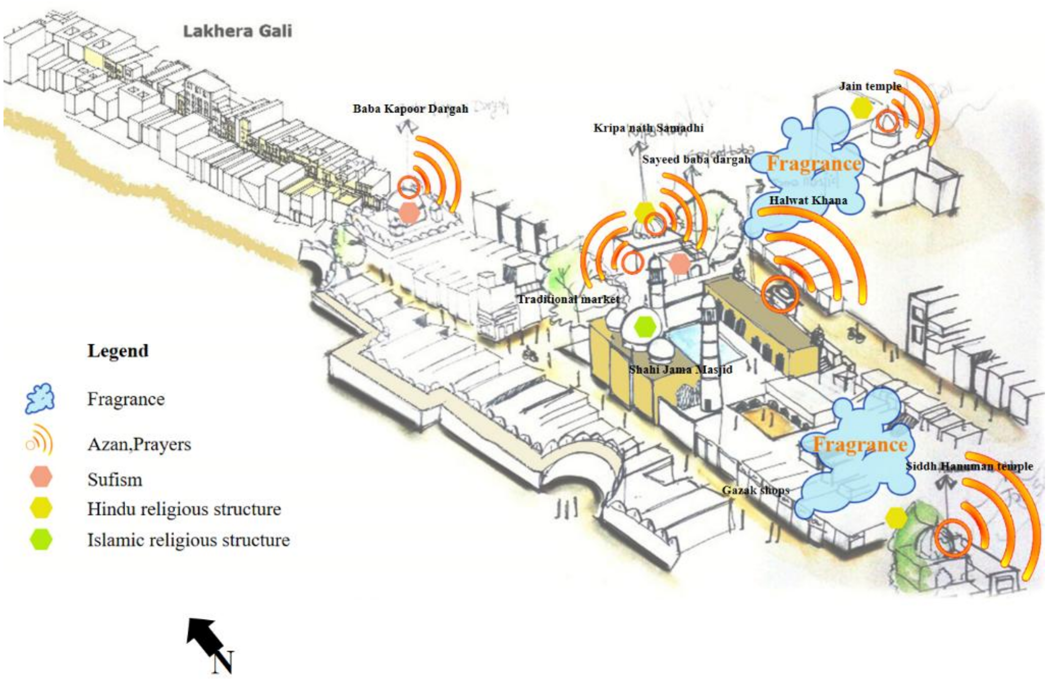


Figure 6 Sensory Exploration: Unveiling the Identity of Shahi Jama Masjid Precinct

Table 1 Showing identified neighbourhood and structures association with the memory.

S.No	Category	Names	Identity with memory associated
1.	**Old Markets**	Chowk Bazar, Chota Bazar, Maddi Ka ka Bazar, Loha Mandi, Sarafa Bazar, Ganj,Ghas Mandi	Markets are known from the 16th C onwards and memory has been associated with the Mughal era in the form of folklore of Jinn's.
2.	**Mohalla**	Golandaj Mohalla, Lakhera Gali, Mewati Mohalla, Jahangir Katra .	The neighbourhoods surrounding Old Gwalior derive their names primarily from community associations, while a few are named after specific events.
3.	**Religious Structures**	Landmark religious structures in the vicinity span from the 10th century to the 18th century. Among the oldest are the Jain Temple, Altumish Mosque, Shahi Jama Masjid, Kripa Nath Samadhi, Sayeed Baba Dargah, Baba Kapoor ki Dargah, and Hanuman Temple, situated close to the fort wall.	Landmark religious structures in the vicinity span from the 10th century to the 18th century. Among the oldest is the Jain Temple. Baba Kapoor, originally a soldier, later transformed into a saint, and the shrine features a battlement parapet erected in his memory.
4.	**Landmarks**	All the religious structures, Halwat Khana gate, Shahi Jama Masjid, Baba Kapoor Dargah, Lakhera Gali, Badalgarh Gate,Soda ka kua.	Landmarks are connected to specific events and structures. Lakhera Gali is renowned for its strong community ties.
5.	**Stepwells**	Noorganj, Jahangir Katra, Khedapati	In different places, the architectural style offered clues about the time it originated, even when not explicitly documented. Remembered through distinctive architectural features, these styles reflect historical and cultural significance. While it no longer serves as a drinking water facility today, the structure is recognized as a step well based on its architectural style. The Noorganj Stepwell has been transformed into a Dargah.
6.	**Festival**	Sufi festival in the month of April at Baba Kapoor Dargah.	Commemorative and continue the tradition.
7	**Structures along roadsides**	Over the years, numerous structures have been abandoned or dismantled due to road widening and urbanization. While some of these structures will persist in memory, others may gradually fade away, eventually becoming forgotten by future generations.	**Error! Reference source not found.** D ismantling of the structures due to road widening along the streets from 2016 onwards.
Inference: The architectural features of the houses like arches, windows, parapets, carvings, and low-height parapets indicate the historical layering of the Old Town of Gwalior. The influence of religious structures on the planning and culture of the old town continues to persist.			

Figure 7 Displaying dismantled structures during the road widening (Rear side of Shahi Jama Masjid).

CONCLUSION

Memories are ingrained within places, structures, precincts, living, and non-living entities, essentially constituting experiences one can sense. Each person's memories tied to a place vary, yet when viewed broadly in the context of a town, these memories are passed down through generations in folklore, stories, arts, and more. Understanding a town's memory involves connecting with a place, which can alter within the same precinct due to changes in event, elevation, approach, architectural form, typology and association of place. A town embodies numerous memories amassed over ages, sometimes overlapping, even as landscapes and surroundings shift. The name and associations endure—a testament to the enduring power of memory in a place. Memories encompass experiences and emotions tied to senses like touch, smell, sound and taste, aiding in interpreting a town's essence. Old Gwalior, positioned on the north side of Gwalior Fort and surrounding the Shahi Jama Masjid, exhibits multiple layers evident in its construction style, architecture, cultural traditions, rituals and beliefs which continue over time. The transformation of Gwalior's old city, particularly evident in its markets and residential areas, showcases a blend of Rajput, Mughal, and Maratha influences. Markets like Chowk Bazar, Chota Bazar, Ganj, Sarafa Bazar, Ghas Mandi, Ganj and Halwat Khana carry historical significance and contribute to the city's unique identity which is associated with the memory of the place. The neighbourhoods, such as Lakhera Gali, Sunaron ki Gali, Raja Ki Mandi , Golandaj Mohalla, Sayadon ka Mohalla were remembered in the name, which was an integral part of the old town. It is evident from the preceding discussion that, in the future, the memories associated with the place may change unless knowledge is transferred to the next generation, allowing individuals to envision them in their minds.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Analysing the image of a city based on the perception of space and mental maps

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Abstract— Every citizen perceives the city differently through their senses, ideology, and mindsets. The stationary and moving elements together form an image of a city to a particular individual. The study aims to analyze how neighborhoods in Pune city are perceived by the natives as well as the migrants from the age groups 18 to 30 years. The study is based on Image of City 1960 by Kevin Lynch who gave the paradigm on the five elements of Imageability namely: Paths, Edges, Districts, Nodes, and Landmarks. These five elements will be the parameters of the study concerning the aspects of Aesthetics, Traffic Points, Social Clusters, Quality of Safety, Sense of Identity, and Special Sensory Experiences. The study will help in the recognition of urban areas through the perception of people as well as the identifying priority zones for future interventions. Identification of the dark/ blind spots and social spots in the study area which will help in improving the imageability. The areas chosen have developed across different time zones with a diversity of natives as well as migrants with different backgrounds. The study will guide the Local authorities, Researchers, and Policymakers in the redevelopment of areas as well as the planning of new areas in the near future. The study concludes that residents have a stronger sense of safety as well as identity in the area whereas migrants have more special sensory experiences in the city.

Keywords: Imageability, Peoples' Perception, Urban Elements, Natives, Migrants

INTRODUCTION

The stationary elements of the city play an important role in our daily lives while we commute from one place to another. Also, the moving elements such as various activities and people play a significant role. The stationary and moving elements together form an image of a city to a particular individual.

Every individual has a separate image of any area or city. These mental maps help an individual in day-to-day life to commute to various places. The mental map helps in the case of exploring a new area, street, or city by observation. Every citizen has perceived the city in different ways in terms of their senses, ideology, and mindsets. We observe diversity in people, Thinking ways, and Upbringing of people. Hence, no person can have the same mental map as the other.

Elements like light, colour, shape, motion, smell, sound, and structure can affect the perspective or image of an area, or city in various forms. Any person can alter their normal behaviour in response to these factors. A city must be planned to avoid negative responses by keeping these factors in mind.

Theory

Kevin Lynch, an influential Urban planner and Author introduced the concept of the 'The Image of the City' in his book, The Image of the City, 1960. He explored how people perceived and mentally mapped the city. He identified the five key elements that contribute to the imageability of a city and these elements influence the mental images that are formed by the observers (Lynch, 1960).

Paths: An observer moves through the channels for example walkways, streets, canals, and transit lines, which are called paths. Along these paths, structures and environmental elements are arranged. Paths are one of the important features in the image of a city. Paths have a directional quality that guides the observers to various places.

Edges: Linear elements that are not paths but rather act as a boundary or outline to the observer. Edges may act as barriers or seem inaccessible. Edges can also act like paths or any physical feature that shows a lateral reference and breaks the continuity of the areas.

Districts are sections of the area that the observer recognizes as an area with similar or common characteristics. Districts can be determined by the characteristics of building type, type of land use or activities, topography, space, or urban form.

Nodes: Nodes are spots or points of the area that are known for their intensive focus and activities in the area. Major concentration of activities can vary from spot to area which may include either a major intersection or a renowned university. Observers mostly notice the transit spots for example train stations or bus stops as their nodes.

Landmarks: Distinct elements that are known by the observers as reference points are known as Landmarks. Landmarks are defined physical structures. Landmarks are easily identifiable and are unique and memorable in context. They can be identified singularly from many other elements which is prominent.

METHODOLOGY

The objective of the study is to study and analyze the perception of natives and migrants about how the people have imaged the elements mentally. Through the literature review (Maria Latypova, 2021), it was ascertained that the sampling population can draw less accurate and limited detailed maps which would be highly subjective and difficult to analyze. The methodology used is the interview of the target population by providing a map of their area and asking them to mark Kevin Lynch's elements.

The study was conducted in two parts: The people were first explained Kevin Lynch's elements with some layman language definitions on a survey sheet. They were asked to mark various elements through various colours on the map, with symbols. The second part consisted of writing the reasons for answering the question.

The target population chosen is between 18 to 30 years of age. This target population was concluded based on a literature review to avoid inaccuracy by the younger as well as the older population. A total of 20 samples were taken for each area. Out of 20 samples, 10 people were natives and the other were migrants. The number of samples was selected based on a literature review wherein the personal interviews were conducted with 30 people.

These parameters are the further factors that can be a reason for the observer by which the elements of the area are identified in the minds of the people.

Aesthetics: This Parameter refers to the visual representation of the various structures that the observer can remember.

Traffic and Transportation: The parameter that the observer perceives the particular element in the form of traffic or used to transport daily

Social Clusters: The observer perceives the element in the form of a crowd or frequent confluence of people at various spots or areas.

Natural elements: The parameter that defines the elements through the natural aspects or man-made areas that are perceived to be natural.

Sense of Identity: Any element that is known for a particular aspect or is named by the government. Any land use or structure that has its own identity.

Sense of Safety: This parameter that the observer perceives the area to be safe or feels to be protected.

Special Sensory Experiences: The observer perceives a particular element through the different types of sensory experiences.

Study area

Pune is a city located in western Maharashtra also known as 'Queen of Deccan'. Pune is known for its history, culture, and diverse population. It houses many industries but is known for the IT industry as well as for its quality of education.

The evolution of Pune dates back to the 17th Century when Peshwas of the Maratha Empire settled down here. Peshwas set up a well-defined layout and Pune was transformed into a well-organized city. The British then in the 19th century established the Cantonment areas which are now known as Khadki and Pune Cantonment. Many renowned institutions were established that made Pune a prominent educational center. After the Independence of India, Pune experienced rapid Urbanization and was also known as Retirement Town. Pune experienced industrialization, especially in the IT and Automotive sectors. Many IT parks as well as townships were planned to accommodate the growing demand. Pune is a part of the smart city mission and various planning and green city initiatives making it the 2nd most livable city in India.

Shivajinagar is a neighbourhood situated on the western bank of Mutha. It is known for its historical monuments and houses various prominent educational campuses. It houses the best streets in Pune for commercial land use especially for street shopping and recreational spaces. Its central location and accessibility contribute to its importance in the overall landscape of the city.

Hadapsar is located on the eastern side of Pune, which has developed after 1990 as the major industrial area which also includes MIDC area, SEZ area, as well as townships and corporate offices. It comprises a mixed cultural population with various residential complexes. Hadapsar has evolved from an industrial center to a diverse and dynamic locality that reflects the broader trends of Pune

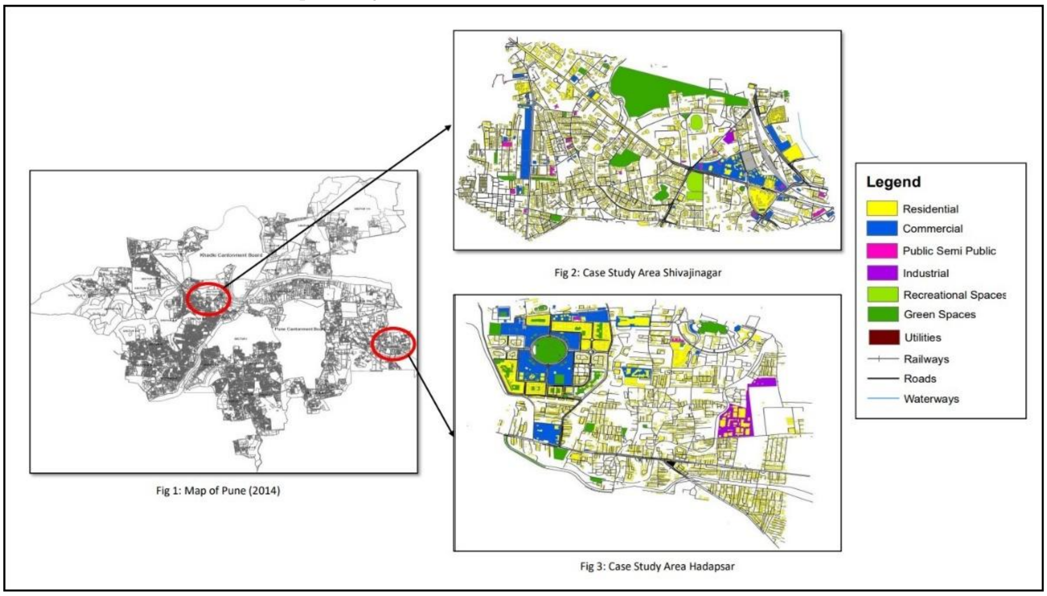

Figure1 : Map of Pune showing Shivajinagar and Hadapsar as its Study Areas

RESULTS AND DISCUSSIONS

It was observed that people could understand and mark Paths and Landmarks faster than other elements. Edges were the most difficult ones to understand, perceive, and mark on the map. The time required for the survey averaged to 10 minutes. Observers especially the migrants found it difficult to mark the elements at the start.

In the Shivajinagar Area, Migrants perceive the Paths through the parameters of Traffic and Transportation whereas the Natives perceive it through the Sense of Identity and Traffic and Transportation. Edges were strongly perceived through the Sense of Identity. By the Migrants as well as the Natives, Nodes were identified by Social Clusters. Migrants perceived the Districts through the parameter of Sense of Identity whereas the Natives perceived through Social Clusters. Landmarks were perceived by Aesthetics, Social Clusters, and Sense of Identity by the Natives, though the Migrants strongly perceived it through their Sense of Identity. Migrants have also perceived the elements through Special Sensory Experiences than the Residents.

In the Hadapsar Area, Migrants perceive the Paths through the parameters of Traffic and Transportation whereas the Natives perceive it through the Sense of Identity. Edges were perceived through the Sense of Identity. By the Migrants as well as the Natives, Nodes were identified by Social Clusters. Migrants perceived the Districts through the parameter of Sense of Identity and Social Clusters whereas the Natives perceived through Sense of Identity. Landmarks were perceived by Social Clusters, and Sense of Identity by the Natives, though the Migrants strongly perceived it through their Sense of Identity. Migrants have also perceived the elements through Special Sensory Experiences than the Residents

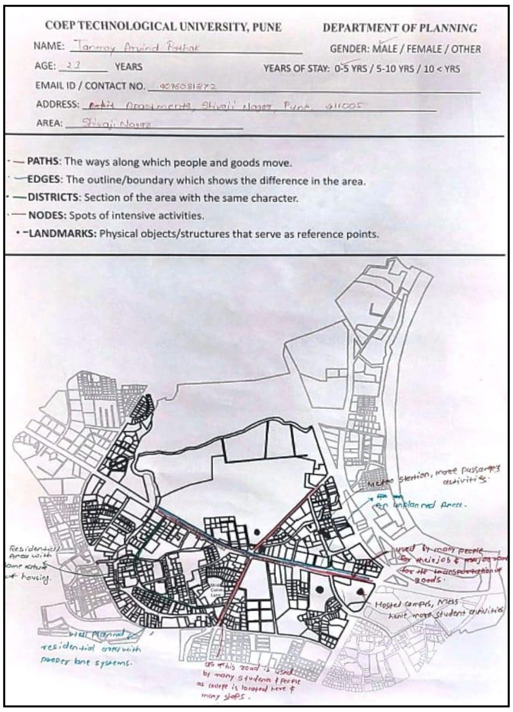

Figure2 : Image of Survey Sample from Hadapsar Area

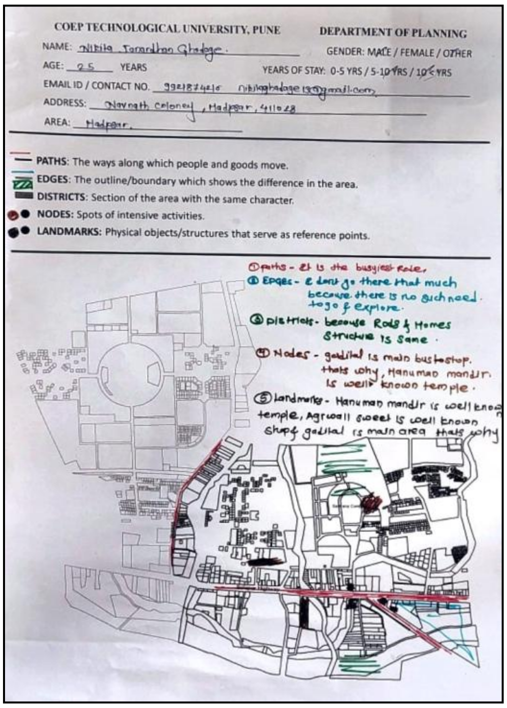

Figure 3 : Image of Survey Sample from Shivajinagar Area

CONCLUSION

Through this research, it is known that people are significantly impacted by the sense of identity that authority has planned. The identity of the roads, structures, and elements as well as the land use of the area is perceived strongly. Also, Traffic Transportation, and Social Clusters are the major parameters that people have frequently imaged. Migrants do have a different perception than Natives as they perceive through their Sensory experiences also. Migrants mostly perceive the area through Traffic and Transportation and Sense of Identity whereas, The Natives image the area through the other parameters.

The findings of the Research can be useful for the authorities for further development and planning of the areas and hence should be undertaken by the authorities to understand the perception and identify the dark spots of the area and make the city more vibrant. It will further help to identify the spots or areas that are not noticed by the authority but have a high influence on the observer.

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How Urban Refugees Claim Space: A Narrative Review

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Abstract— Geo-political conflicts have increased forced displacement and driven a significant portion of refugee populations to seek shelter in urban areas worldwide. Understanding how these vulnerable urban refugee groups claim their 'right to the city' is crucial for informed policy-making and the development of supportive interventions. This narrative literature review searches and analyzes select peer-reviewed articles from diverse disciplines and geographic contexts. We identify the intersections of legal uncertainties, persistent threats of discrimination and exclusion and other challenges in social-cultural integration that complicate refugees' struggle for urban space. The paper aims to provide a narrative overview of how urban refugees exercise agency to claim space, resisting power structures through everyday socio-spatial "tactics". The theoretical framework, grounded in concepts of "right to the city" guides both the selection and interpretation of the literature. The key themes emerging from the review are grouped under Resisting Power Structures, Community Consolidation, Activism and Refugee Identity, and Spatial Appropriations and Resilience. Our analysis acknowledges the specific experiences of urban refugees in the Global South. The review concludes with future research directions, suggesting comparative studies, longitudinal research, and advocating for the active engagement of refugee communities in participatory action research design, local and national policy-making and implementation.

Keywords: Urban Refugees; Right to the City; Spatial Tactics; Refugee Integration

INTRODUCTION

The United Nations High Commissioner for Refugees (UNHCR) Global Appeal 2024 reports that an unprecedented 130.8 million people are displaced which amounts to roughly 1 percent of humanity (UNHCR, 2024). UNHCR policy on refugee protection and solutions in urban areas (2009) states that almost half of the world's refugees now reside in cities and towns, marking a significant departure from traditional encampment settings (UNHCR, 2009). Marginalized urban populations navigate complex social, economic, and political terrains in their quest for stability, acceptance, and empowerment. The escalating urban refugee crisis, intertwined with complex geopolitical realities, intensifies these urban conflicts over access to essential resources, cultural recognition, and fundamental human rights. Countries in the Global South, often grappling with their own socio-economic challenges, are also affected by these refugee movements.

The three solutions for refugees that the UNHCR advocates for, include voluntary repatriation, resettlement in a third country, and integration within the local community of the host country. Long (2013) illuminates the challenges and ethical quandaries surrounding repatriation and highlights the discrepancy in "States' actions between rhetoric and practice. Long advocates for a new approach that includes active involvement of refugee communities, consent, and consideration of alternatives to physical return (Long, 2013). Jacobsen (2001) argues that local integration, often overlooked in favor of other solutions, can be a viable and cost-effective alternative to camps, particularly when accepted by host governments. Hovil and Maple (2022) critique the neglect of local integration at various governmental levels. The authors argue that the interplay of global, national, and local dynamics has eroded the feasibility of local integration as a sustainable solution in the political discourse. This occurs even as refugees proactively seek engagement with communities and labor markets, actions that frequently stand in opposition to prevailing policies (Hovil & Maple, 2022). Kraler et al. (2022) further this discussion by reviewing integration policies within the EU, advocating for a holistic approach to migrant integration that encompasses local infrastructure improvements and gender-sensitive employment policies. Schinkel (2018) critiques the concept of "immigrant integration" within Western Europe, challenging the associated research for its conceptual shortcomings and neocolonial underpinnings, sustaining a narrative that privileges certain groups while excluding others. He encourages a more imaginative approach that considers the complexities of migration and urges researchers to move beyond policy categories.

Set against the backdrop of contemporary urban refugee crises, this study poses a critical inquiry: How do urban refugees, often marginalized and viewed as passive entities, resist power structures and claim urban space through everyday spatial tactics? This paper aims to review the scholarly discourse on how refugees navigate and transform their urban settings, thereby providing valuable perspectives for policymakers, academics, and community organizers to create more inclusive and adaptive urban environments.

METHODOLOGY

This narrative review is structured to methodically address this question, beginning with an introduction and followed by a methodology section that outlines the literature selection criteria and theoretical framework. The review then thematically analyzes the urban refugee tactical responses and culminates in a discussion on future research directions, aiming to enrich the dialogue on creating responsive urban environments.

Bibliographic Research Strategy

In conducting our narrative literature review, we adhered to the methodological recommendations provided by Green, Johnson, and Adams (2006) and partially aligned our approach with the guidelines outlined by Petticrew and Roberts (2006). Our exploration covered key academic databases including SCOPUS, Web of Science, and Google Scholar, recognized for their exhaustive coverage of scholarly literature across diverse fields such as social sciences, urban studies, migration studies, and refugee studies. We developed a comprehensive list of keywords and Boolean operators to guide our search. Terms included "urban refugees," "spatial tactics," "refugee integration," and "right to the city," among others. These terms were used in various combinations to maximize the retrieval of pertinent studies. Our inclusion criteria focused on peer-reviewed journal articles, books, and scholarly reports published from 2000 to 2024 to focus on contemporary scholarship. We excluded non-peer-reviewed sources, articles not available in English, and those not directly addressing our research interest. We employed a two-stage screening process. The initial screening was based on titles and abstracts, followed by a full-text review to ensure alignment with our research objectives. This process ensured that selected publications were pertinent to the central themes of urban refugee spatial tactics and contributed significantly to our review.

Urban Refugee Vulnerabilities and Agency

In the discourse on urban refugees, two crucial dimensions emerge: the socio-legal challenges they face, and the evolving recognition of their agency. Refugees face a range of risks, like "the threat of arrest and detention, refoulement, harassment, exploitation, discrimination, inadequate and overcrowded shelter, as well as vulnerability to sexual and gender-based violence (SGBV), HIV-AIDS, human smuggling and trafficking" (UNHCR, 2009). Hostilities and xenophobia, manifesting in discrimination, harassment, and violence, are compounded by negative stereotypes and misconceptions, leading to social exclusion. Yet, the academic narrative on urban refugees has notably evolved from portraying them as mere victims or recipients of aid, to active contributors to society, recognizing their agency and resilience. For instance, Kibreab's (1993) research in Somali refugee camps illustrates the refugees' resourcefulness and determination to maintain independence and cultural identity, even in adverse conditions, challenging the notion of a 'refugee mentality' dependent on assistance. It emphasizes the importance of recognizing and supporting refugees' capacities and willingness to participate in economic activities (Kibreab, 1993). Refugee agency however depends on the complex interplay between legal structures, societal norms, and the lived experiences of refugees in cities. The acknowledgment of refugee agency aligns with the goal of self-reliance, defined by the UNHCR as the ability to meet essential needs in a sustainable manner (UNHCR, 2005). Emphasizing self-reliance not only challenges stereotypes but also highlights the potential for refugees to contribute meaningfully to their host communities. It is this idea that frames our decision to discuss urban refugee spatial tactics in this review.

Our narrative literature review unfolds iteratively, avoids a strict structure, and is grounded in a framework that draws from urban studies and human geography. Central to our exploration is the concept of the 'right to the city,' as introduced by Henri Lefebvre (1968) and further developed by David Harvey (2008), which underpins our understanding of urban refugees' spatial and political claims. Henri Lefebvre first introduced the idea in his 1968 book "Le Droit à la Ville," as not just a “cry and demand” for access to urban resources but for wider political inclusion. David Harvey (2008) expands on Lefebvre's ideas in "Social Justice and the City," and delves into how cities become arenas for capital accumulation and class struggle. As Harvey eloquently states, "The right to the city is far more than the individual liberty to access urban resources: it is a right to change ourselves by changing the city" (Harvey, 2008). Massey's (1993) concept of "power-geometry" also reveals the intricate power dynamics in urban spaces. Don Mitchell (2003) frames public space as a battleground where exclusion and resistance play out and argues for equitable access to urban spaces and the opportunity to participate fully in urban life for all marginalized groups. Soja has also notably argued that justice has a geography, advocating for the equitable distribution of resources and access as foundational to achieving social justice (Soja, 2010). Purcell (2013) discusses the implications of the right to the city in modern urban governance and planning contexts. Gotham (2003) argues that the urban poor are active spatial actors who navigate, contest, and reshape their environments in response to various constraints. Gotham posits that spatial boundaries, identities, and meanings are not fixed but are actively negotiated, defined, and produced through social interactions. Sanyal (2012) draws parallels between refugees and the urban poor, as agents capable of shaping spaces that align with their political and social needs (Sanyal, 2012). Urban informality thus becomes a pertinent concept, enabling a reconsideration of refugee politics as a form of 'gray spacing' and emphasizing how refugees, like the urban poor, engage in informal resistance against oppressive power structures (Sanyal, 2012).

How the powerless resist and navigate hegemonic structures in their daily lives has been explored by Michel de Certeau in The Practice of Everyday Life (1984). De Certeau contrasts "tactics," the artful everyday practices with "strategies," the mechanisms utilized by those in positions of authority to delineate and dominate spaces. Tactics are described as acts of "everyday creativity" or clever maneuvers that individuals employ within the spaces controlled by others, embodying the victories of the "weak" over the "strong" (De Certeau, 1984). These tactics rework the configurations of disciplinary power from within, subtly undermining the dominant order without directly challenging the legitimacy of sovereign power. Applied to the context of urban refugees, these tactics highlight the significance of everyday practices as sites of resistance and agency.

Scope of the Review

Pertinent aspects such as the critical examination of identity labels like refugee, internally displaced person (IDP), and migrant, alongside refugee rights, urban citizenship, both national and international legal structures, cultural clashes, frameworks for assimilation and integration, and state reactions, play a crucial role in understanding the experiences of urban refugees. Each of these topics is complex enough to merit its own dedicated literature review. The body of literature on urban refugees is extensive, multidimensional, and rich, even when restricted to English language sources. For the purpose of this paper, our focus remains strictly aligned with our overarching objective of understanding how urban refugees negotiate their rights to urban spaces. The thematic layout presented herein attempts an overview, but it is important to note that developing each of these themes comprehensively is also beyond the scope of the paper.

NARRATIVE OVERVIEW OF SOCIO-SPATIAL TACTICS OF URBAN REFUGEES

Assimilation is the process by which refugees fully adopt the dominant cultural norms , values, and lifestyles of the host country, while integration is viewed as a process where refugees or immigrants maintain their own cultural identity while also adapting to and participating in the life of the host country. Recent academic and political debates have seen an increase in the use of labels such as “sanctuary cities” (Darling & Bauder, 2019), “solidarity cities” (Agustín & Jørgensen, 2019), and “Cities of Welcome” (Bazurli, 2019). Our study is framed through the lens of urban integration dynamics as conceptualized by Strang and Ager (2010). Their framework delineates a multi-faceted approach to integration, identifying rights and citizenship as foundational elements; language, cultural knowledge, safety, and stability as facilitators; social capital as a means of fostering social connections; and employment, housing, education, and health as both indicators and facilitators of integration (Strang & Ager, 2010). These processes can lead to spatial clustering as refugees seek familiar cultural environments. Socio-spatial segregation can escalate into more extreme forms, such as ghettoization, intertwining racial, economic, and social marginalization, creating complex layers of isolation (Wacquant, 2008). The interplay of associated cycles of poverty and violence underscores the need for inclusive urban planning and policy-making promoting integration (Seethaler-Wari, 2018; Hinger, 2019). Despite the critical roles these domains play, the interrelationships among them remain intricate and underexplored.

Resisting Power Structure

Here we discuss how urban refugees challenge entrenched systems and redefine traditional concepts of citizenship and belonging. In exploring contested spaces of citizenship, Maestri and Hughes (2017) argue that political subjectivities emerge from the urban space through everyday acts, dwelling, and working. The authors analyze camps, borders, and urban encounters, demonstrating how these spaces contribute to the emergence of new contested political subjectivities from the margins. The urban is portrayed not only as a space of social order but also as a space of disruption of inequalities.

State Responses and Institutional Frameworks

Despite the existence of international legal frameworks like the 1951 Refugee Convention and its 1967 Protocol, the application and interpretation of these agreements vary significantly across host countries. This variation leaves some refugees in precarious positions. Giorgio Agamben's (1998) concept of "bare life" (vita nuda) focuses on how individuals can be reduced to their biological existence and controlled or eliminated by sovereign power without legal consequences. Agamben's work on the "state of exception," (2005), delves into the suspension of normal legal and political rules by governments, which they justify as a response to emergencies or threats. Together, these concepts illuminate the structural mechanisms by which refugees are subjected to the arbitrary exercise of power. Responses to urban refugees are influenced by a host nation's legal frameworks, economic conditions, political climates, and historical experiences with displacement, ranging from inclusive approaches to those framing refugees as security or economic threats. Betts, Loescher, and Milner (2012) discuss how the UNHCR has continuously adapted its mandate in response to political and institutional changes, but there is still the need for political analysis, even-handedness, and effective partnerships. Obradović-Wochnik (2018) delves into the intersection of biopolitical rationalities and neoliberal capitalism in Belgrade, revealing how state authorities, in collaboration with various actors such as property developers, business owners, residents, migration workers, and police, employ seemingly mundane practices to restrict public space use by refugee. These practices, including evictions and demolitions, aim to encourage refugee registration in official camps. Despite resistance from aid organizations and activists, the state's narrative often prevails, framing camps as the only 'legitimate' spaces for refugees, providing authorities with a narrative that legitimizes eviction from commercial spaces while designating camps as 'legitimate' spaces for refugee populations (Obradović-Wochnik, 2018).

Bazurli and Kaufmann (2023) explore insurgent asylum policies in European cities, noting the emergence of "sanctuary cities" and "welcoming cities" as critical arenas where state and societal boundaries blur. Comparing Barcelona, Milan, and Munich during the 2010s "refugee crisis," the study reveals varied responses. Barcelona and Milan, exceeding jurisdictional boundaries, supported migrants considered "illegal," while Munich focused on integration programs. The varied responses highlight how city governments navigate multi-level governance dimensions to shape insurgent urban asylum policy-making. Wood, McGrath, and Young (2012) highlight the importance of connecting immigration and settlement policies with urban planning in Calgary, advocating for social infrastructure that fosters civic participation and reduces marginalization. Framing it through emotional geography literature, they argue that settlement logistics are both emotional and pragmatic, influenced by personal connections with settlement workers and the city's accessible public spaces (Wood et al., 2012). Similarly, Neis, Meier, and Furukawazono (2018) emphasize the critical role of acclimatization in German cities, identifying effective communication, language learning as key factors in refugee integration. Housing design also emerges as a pivotal aspect, with challenges posed by the rapid influx of refugees and the significance of innovative patterns, such as the "Visitor Room." The authors argue for the introduction of new legislation to address the complexities of the refugee crisis at the local level (Neis, Meier, and Furukawazono, 2018).On a positive note, Jonathan Darling's work on refugee urbanism, particularly his analysis of Sheffield as the UK's first 'City of Sanctuary', provides a nuanced understanding of how cities can embody a culture of hospitality towards asylum seekers and refugees. This involves not just welcoming refugees into urban spaces but also critically engaging with the policies and practices that govern asylum and refuge (Maestri & Hughes, 2017).

Liminality and Citizenship

Urban refugees often find themselves in liminal spaces, where their legal status, rights, and identities are in flux. This liminality, however, becomes a ground for active citizenship and political subjectivity, as refugees navigate and contest the urban landscapes that host them. The concept of urban citizenship, as argued by Bauböck (2003), necessitates emancipation from national constraints. Bauböck (2003) advocates for reforms that empower local self-governance and establish formal local citizenship that is disconnected from nationality. This redefinition of citizenship at the municipal level is crucial for enhancing the rights and autonomy of urban refugees, proposing a model that potentially overcomes the exclusionary aspects of national citizenship (Bauböck, 2003). The introduction of "Cities of Refuge," as explored by Oomen (2020), further illustrates the potential for renegotiating refugee rights and fostering a cosmopolitan citizenship within urban environments.Sigona (2015) challenges Agamben's (2005) conceptualization of refugee camps as "spaces of exception" and proposes the term 'campzenship' to capture the nuanced political membership emerging within and around camps. Through ethnographic insights from nomad camps in Italy, the article explores the interplay between social, spatial, and political dimensions within the camp, revealing it as a complex terrain shaping rights, entitlements, and political subjectivation through daily interactions. Bazurli (2019) adds a critical dimension to this discussion by noting the importance of alliance-building with local governments and social movements. He states that "alliance-building is a strategy to secure political gains while shaping policies within an otherwise unreceptive, hostile context" (Bazurli, 2019). This suggests that strategic alliances are a vital part of refugees' tactics to improve their living conditions and influence urban policies.

Community Consolidation

The theme covers the formation and impact of community networks and the significance of refugee-led initiatives for economic autonomy and cultural integration.

Cultural Exchanges and Advocacy for Integration

By examining the roles of advocacy groups and cultural practices in sanctuary cities, we can gain insight into the dynamic ways through which urban environments evolve to be more inclusive and supportive of refugees. Oomen (2020) highlights the innovative approaches cities take in becoming sanctuaries or cities of refuge, where they actively develop strategies for refugee reception and integration. These cities contribute to shaping international refugee law and policy by challenging national governments and fostering a de facto inclusive form of "cityzenship." This concept emphasizes the importance of local practices and cultural processes in redefining global citizenship and the future of the nation-state. Cultural expressions, including theatre, arts, music, and speeches by civic leaders, are central to crafting inclusive urban cultures that legitimize welcoming practices. Such cultural processes, often embedded within transnational networks like "Fearless Cities," are intertwined with local traditions and practices, showcasing the pivotal role of culture in facilitating community solidarity (Oomen, 2020). Building on the importance of local initiatives, Batuman (2021) also underscores the role of advocacy groups and cultural exchanges. These groups act as critical platforms for articulating refugees' rights and concerns, thereby influencing the discourse on urban refugee policy making. Such refugee-led initiatives significantly enrich the social and cultural tapestry of urban environments, empowering refugees to redefine their narratives and identities and contribute to the diversity and vibrancy of host communities. Steigemann & Misselwitz (2018) further imply that the spatial appropriation by refugees for cultural activities can lead to positive interactions and cultural exchanges between refugees and local communities, fostering a mutual respect and understanding that is essential for the successful integration.

Economic Self-Reliance through Community Networks

Community networks, rooted in cultural and social capital, play a crucial role in enabling refugees to navigate the complexities of urban economic landscapes. Bhimji (2016) explores how refugees leverage their cultural practices and social connections to initiate economic activities. Betts, Omata, and Sterck's study (2020) underscores the significance of social networks in the context of urban refugees' reluctance to relocate, emphasizing the spatial dimension of these networks. Urban refugees heavily rely on established social networks, encompassing family, friends, and community ties, as integral components of their economic self-reliance. Many refugees perceive relocation as a disruptive force that could sever their vital social networks, which they consider essential for their socio-economic prospects. It highlights that the relative location of these networks within the city is a critical factor, and their spatial arrangement is not easily negotiable through top-down technocratic decision-making (Betts, Omata, & Sterck, 2020). Grabska (2006) provides a compelling case study of Sudanese refugees in Cairo, illustrating how the establishment of schools, lending centers, housing initiatives, and refugee associations not only addresses community needs but also facilitates participation in the urban economy and culture. This active engagement with the urban environment underscores the potential of refugees to contribute meaningfully to their host cities, mitigating xenophobic tensions and unlocking economic and social potential (Grabska, 2006). Recognizing and supporting these networks and contributions is essential for enhancing the economic self-reliance and overall well-being of urban refugees.

Betts and Collier (2017) emphasize the importance of economic self-reliance for refugees, arguing that prohibiting their right to work constitutes a "catastrophic error." They suggest that a well-regulated capitalism, coupled with an ethical "duty of rescue" and "corporate social responsibility," can rejuvenate the global humanitarian regime. This approach aims to create "new havens" that enable refugees to regain economic autonomy (Betts and Collier, 2017). Their argument aligns with the foundational principle of self-reliance in refugee studies. Steigemann & Misselwitz (2018) further link the concept of space to economic self-reliance, illustrating how refugees utilize urban spaces not just for habitation but also for economic activities, drawing on their cultural and social capital. These networks, often more accessible and responsive than formal aid structures, operate as critical support systems.

Refugee Identity and Activism

Here, we discuss the evolving understanding of urban spaces as platforms for refugee activism and identity assertion. Sanyal (2014) challenges the predominant view of refugee spaces as purely biopolitical and explores the politics of space within refugee camps through the lens of urban debates. Drawing on case studies from the Middle East and South Asia, she examines how refugee spaces are produced informally and how individuals reclaim agency by actively "producing spaces" both physically and politically. By drawing parallels between refugee camps and urban marginalities, Sanyal's research highlights refugee spaces as crucial arenas for expressing new political identities and claims (Sanyal, 2014). Elwood (2006) explores the dynamic roles and strategies of community organizations in urban planning and problem-solving, challenging the conventional binary of cooptation versus resistance. Through ethnographic research with community organizations in inner-city Chicago, Elwood demonstrates how these groups employ geographic information systems (GIS) to create spatial narratives that reflect local needs, conditions, and assets. Elwood's findings are highly relevant here, as they underscore the potential of community organizations and urban refugees to leverage spatial narratives and information technologies for strategic purposes (Elwood, 2006). So strategic utilization of spatial narratives and technology, alongside the informal production of space, emerges as critical in understanding urban spaces as platforms for refugee activism and identity assertions.

Territorial Stigma

Winchester and White (1988) examine socio-spatial processes of gentrification, polarization, and marginalization within the inner city of Paris and elucidate how deindustrialization, demographic changes, state activities, and ideological shifts have contributed to increased tensions and the categorization of marginalized groups. Based on their case studies of down-and-out groups in 1980s Paris, the authors assert that developments in the inner city intensify the struggle between interests of wealth, power, social acceptability, and legality and their opposites (Winchester & White, 1988). In detailing contemporary urban socio-spatial dynamics, Wacquant (2008) introduces "advanced marginality" to describe new forms of social exclusion and poverty, characterized by spatial concentration and the stigmatization of specific urban areas. His concept of "territorial stigma" suggests that some urban neighborhoods are negatively labeled, reinforced by media portrayal, public discourse, urban policy, and historical reputation (Wacquant, 2007). Vaughan (2005) explores the nuances of physical segregation and economic marginalization in the context of 19th-century and contemporary London, utilizing GIS systems and space syntax methods. Vaughan's findings underscore the complex socio-spatial processes that lead to the formation of impoverished areas and their interplay with immigrant populations, setting the stage for understanding the specific challenges faced by urban refugees (Vaughan, 2005). The concept of territorial stigma, as discussed by Link & Phelan (2001) and Wacquant (2007), highlights how negatively labeled areas inhabited by marginalized communities perpetuate cycles of poverty and exclusion. Batuman (2021) says, in this context, that the “biopolitics of nationless bodies has a spatial character that is based on organized immobility.” Batuman (2021) identifies five spatial forms: mobility, state-controlled incarceration, refugee camps, the new urban condition, and forced migration's effects on cities. Adding another layer to this complex landscape of ghettoization and territorial stigma, Sampson and Raudenbush (2004) investigate how implicit bias influences perceptions of disorder in urban neighborhoods, demonstrating how concentrations of minority groups and poverty can intensify residents' perceptions of disorder. The authors suggest that seeing disorder is laden with social meanings beyond essentialist theories, leading to self-reinforcing processes that contribute to the perpetuation of urban racial inequality (Sampson & Raudenbush, 2004).

Cultural Identity and Representations

One crucial aspect of cultural preservation for refugees in urban environments is their ability to communicate and negotiate their identity. The first step in understanding how the themes of cultural identity, representations, and urban adaptation intersect in their struggle for space, is to recognize the conventional portrayals of migrant identity. Vaiou and Stratigaki (2008) challenge the dichotomy of migrant identity portrayed either as refugee 'communities' or as part of "diaspora and hybridity, as resistance to constructions of place-bound `communities'." They examine the construction of local, transnational, and imagined communities among Albanian migrant women in Athens and highlight the importance of informal support practices and social services in shaping migrant women's sense of belonging and negotiating gender relations (Vaiou & Stratigaki, 2008). Benjamin (2008) in "Occupancy Urbanism" illustrates how marginalized groups, which may include refugees, negotiate urban spaces in ways that maintain their cultural identity. This negotiation involves a sophisticated interplay of adaptation and assertion within urban landscapes. Misselwitz and Steigemann (2022) explore the communicative dimensions of spatial practices within refugee camps in Berlin. They demonstrate how spatial practices function as nonverbal forms of communication, much like language. These practices, which (re)configure spaces, play a pivotal role in constructing, reconstructing, and deconstructing meaning, norms, and values. Such practices can serve as a means of preserving cultural identity and create hybrid configurations that bridge institutional norms, becoming substitutes for language when engaging with neighbors, camp management, or regulatory regimes (Misselwitz & Steigemann, 2022). Sanyal (2014) observes such spatial transformations, emphasizing how refugee camps can morph into microcosms of cultural preservation and adaptation. Bhimji (2016) adds depth to this narrative by highlighting the creation of spaces within urban environments as vital nodes for cultural expression. These spaces serve as living representations of refugees' cultural heritage, juxtaposed against the backdrop of the new urban landscapes (Bhimji, 2016).Canedo and Elmouelhi (2023) challenge traditional assimilation-based approaches to integration. They emphasize the transformative potential of spatial changes in public spaces, particularly communal areas. Through case studies in Irbid, Jordan, and Berlin, Germany, they reveal how collaborative research with refugees underscores the significance of communal spaces beyond housing and employment. The quality of life for refugees is influenced by the articulation between these communal practices and the involvement of local actors, whether institutional or non-institutional (Canedo & Elmouelhi, 2023). While the preservation of cultural identity is a crucial aspect of refugees' urban adaptation, it is thus essential to consider integration from a broader perspective.

Political Activism and Visibility in Public Spaces

Amin (2008) explores how collective culture and urban public space serves as a "pre-cognitive template for civic and political behavior." Relevant to urban refugees, this perspective suggests that the distinctive urban collective culture can impact the visibility and political engagement of refugees in public spaces. Iveson's (2013) examines micro-spatial urban practices of "DIY Urbanism", which are also employed by refugees to assert new forms of authority and equality in urban settings. Hall (2015) elucidates how urban refugees transform everyday practices into acts of resistance and political reconfiguration, by actively participating in the creation and negotiation of shared spaces, such as streets, through movement, mixing, and exchange. This resistance is manifested in the migrants' ability to stretch their capacities, grow networks, and create new platforms of civility and public discourse. These acts of making and remaking urban spaces enable refugees to contest and reshape notions of identity, belonging, and community (Hall, 2015).This perspective complements the observations of Sanyal (2014), who discuss that this activism is not merely a physical occupation of space but a political statement, redefining refugees' visibility and agency within the urban landscape. But it also potentially heightens vulnerability to discrimination. Batuman (2021) explores how visibility in urban spaces can redefine the interactions of refugees with host societies, influencing their inclusion or marginalization. This visibility becomes a double-edged sword, shaping their access to resources and societal integration (Batuman, 2021). Swerts (2017) explores undocumented activism in Chicago and Brussels, highlighting how urban spaces serve dual roles: as safe spaces for reimagining subjectivities and as public stages to claim rights. He argues that more attention needs to be paid to the "'urban interstices' or the spaces in between legality and illegality, visibility and invisibility and formality and informality that allow unrecognized actors to simultaneously stay 'out of sight' and 'be seen'" (Swerts, 2017). A framework proposed by Swerts and Nicholls (2020) outlines two logics of collective action- disruption and reproduction- that continually manifest in undocumented immigrant rights mobilizations. It is important to note that reproduction here means cases where activists may conform to status quo language and solutions, potentially reinforcing exclusionary practices (Swerts & Nicholls, 2020).

Bhimji (2016), following Lefebvre, frames urban struggles of refugees as a confrontation between "abstract space" (a mental space where refugees are marginalized) and "representational space" (a symbolic space where refugee activists and their supporters strive for visibility, express their ideologies, and push for political change). The spatial protests encompass broader refugee demands as these contested spaces ultimately enable refugees to gain visibility and promote alternative discourses (Bhimji, 2016). Hemmersam, Breivik-Khan, Ip, and Selmer-Olsen (2022) provide further insights into the role of urban public spaces in addressing displacement challenges within Norway. They emphasize the importance of thoughtful design and management of urban public spaces and local neighborhood centers, asserting that such measures can significantly enhance the well-being of migrants and facilitate cross-cultural interactions within host communities (Hemmersam et al., 2022). Gill, Conlon, Tyler, and Oeppen (2014) delve into the socio-spatial tactics employed by migrant and asylum support groups (MASGs) in the context of increasing migration control by states. Their research explores how these groups infiltrate securitized spaces, appropriate control technologies, and exploit the inconsistencies within the neoliberalization of migration controls. These tactics, which include both material and symbolic acts like detainee hunger strikes and lip sewing, as well as peaceful protests and legal support in courts, are carried out within "enemy territory" and seek to alter the conditions and experiences of asylum seekers and irregular migrants incrementally. This demonstrates the adaptability of refugees in their pursuit of political visibility and relevance (Gill, Conlon, Tyler & Oeppen, 2014). footnote

Resilience through Spatial Appropriations

Iveson (2013) delves into the transformative potential of do-it-yourself (DIY) urbanism, arguing for its role in fostering a democratic urban landscape. By establishing "cities within the city," DIY urbanism practices such as guerrilla gardening and community-led initiatives can challenge traditional authority and offer alternative public space uses. However, Iveson cautions that without politicization—linking individual urban practices to a broader urban politics of inhabitation—these efforts may fall short of contributing to democratic urban politics. This assertion highlights the need for refugees and migrants to engage in politicized actions to ensure their contributions to urban spaces are recognized and valued (Iveson, 2013). Darling (2020) introduces "refugee urbanism," using a "seeing like a city" framework to explore how urban settings enable asylum seekers to navigate and resist governance through everyday practices. This approach sheds light on the emergence of new forms of knowledge and expertise among refugees, who exploit the complex spatial relations of authority and accountability in urban environments. Darling's concept of "refugee urbanism" complements Iveson's emphasis on politicization by demonstrating how spatial appropriations—whether through creating community spaces or participating in informal economic activities—require an assertion of rights and the formation of new political subjectivities. Konduri and Lee (2023) examine migrant spatial integration in Busan, South Korea and mark a "local turn" in migrant spatial integration, creating new urban geographies characterized by "humanitarian" and "migrant" urbanism. They advocate for strategies that involve multi-level governance and recognize migrants not as outsiders but as integral members of the local demographic and contributors to the workforce (Konduri & Lee, 2023).

Informality and Bio-political Presence

Building on the thematic foundations of Giorgio Agamben's (2005) "state of exception" and De Genova’s (2002) claim of sociopolitical construction of 'illegalization’ we discuss scholarly insights on the interplay between informality, bio-political presence, and legal frameworks that shape the experiences of refugees in cities. Koizumi and Hoffstaedter (2015) offers insights into the challenges faced by refugees in urban settings, examining issues such as status recognition, the role of international and national actors, housing, education, and integration. The metaphorical description of refugees being "caught between a snake and a tiger" captures the anxiety and hopelessness experienced by urban refugees (Koizumi & Hoffstaedter, 2015). This perspective urges a reevaluation of the implications and negotiation of rights in these alternative spaces (Martin, 2015). Martin (2015) examines the complexities of the Palestinian refugee camp of Shatila in Beirut, problematizing the conventional understanding of 'bare life' and 'camp' as proposed by Agamben. The concept of 'campscapes' is introduced to analyze the entangled spaces of the camp and the city, challenging the idea that camps are solely spaces of exception. The author argues that refugee camps, such as Shatila, are evolving, permanent solutions, serving as laboratories for political experiments. The paper emphasizes the need for political geographers to adopt new spatial analysis frameworks and addresses the limitations of exclusively legal perspectives on exclusion. Darling (2017) points to the politics of presence as a key concept , allowing refugees to assert their presence not just as a social fact but as a transversal connection to the city. Such presence pushes for a reevaluation of the rights to the city beyond hospitality, towards a framing of justice that acknowledges refugees' contributions and rights as urban citizens (Darling, 2017). Echoing these themes, Gotham (2003) and Sanyal (2012) discuss how urban refugees encounter and navigate various legal frameworks that influence their access to and use of urban spaces.

Access to Housing and Innovative Use of Urban Infrastructure

Seethaler-Wari (2018), exploring refugee integration dynamics in Göttingen, Germany, provides an essential starting point by emphasizing the critical role of local factors like housing location. This perspective underlines the necessity for context-specific solutions that address the challenges and institutional arrangements influencing asylum-seekers' lives, suggesting that tailored strategies at the local level are fundamental to fostering integration. (Seethaler-Wari, 2018). Building on the idea of localized responses, Meeus, van Heur, and Arnaut (2019) introduce the concept of "arrival infrastructures," referring to the urban fabric that entangles newcomers upon their arrival, shaping future social mobility. This concept challenges linear settlement approaches by advocating for a multidirectional understanding of arrival, emphasizing the continuous emergence of infrastructure from social practices. Phillips (2006) further examines the challenges to refugee housing integration in Britain, identifying key obstacles such as conflicting local government agendas, gaps in housing provision, and the impact of racial harassment. This analysis points to the importance of partnerships with voluntary organizations and culturally sensitive provisions (Phillips, 2006). To conclude our discussion on urban refugee spatial structures, we turn to the framework proposed by Alawneh and Rashid (2022) aimed at enhancing the resilience of urban refugee neighborhoods. They emphasize connectivity, efficiency, diversity, redundancy, and modularity as essential elements in designing refugee spaces that prioritize security, stability, inclusion, functionality, and livability- a systematic approach to well-being of urban refugees(Alawneh & Rashid, 2022).

Complementing these structural considerations, are studies which highlight the adaptability and ingenuity of refugees in utilizing urban spaces. Benjamin's (2008) concept of "Occupancy Urbanism" and subsequent observations by Wood, McGrath, & Young (2011), Lelandais (2014), Tsavdaroglou (2020, 2021), and Bhimji (2016) detail how refugees creatively repurpose urban areas to meet their needs, often transforming neglected spaces into vibrant community hubs. By fostering environments that support innovative housing solutions and the creative repurposing of urban spaces, cities can enhance the resilience, integration, and socio-economic inclusion of refugee populations.

Urban Refugees in the Global South

The UNHCR Global Trends report (2022) reveals that 80% of displaced individuals globally reside in countries grappling with severe food insecurity and malnutrition, often in areas also confronting climate and other disaster risks. Additionally, the report highlights that over 85% of refugees find asylum in developing countries, typically those bordering their own country of origin (UNHCR, 2022). The Global South urban condition presents challenges characterized by rapid urbanization, inadequate infrastructure, socio-economic inequalities, and limited access to formal employment opportunities for vulnerable populations, including urban refugees, and such socio-political landscapes of host cities play a crucial role in shaping their spatial tactics. The case study by O'Loghlen and Bwami (2018) on urban refugees in Dar es Salaam, Tanzania, emphasizes the importance of granting freedom of movement to refugees, allowing them to live outside camps for employment and security. In such rapidly growing cities, integration challenges are exacerbated by limited resources and urban growth, necessitating support from urban institutions.The right to work is identified as crucial, with recommendations to improve access to business licenses and work permits, exempt refugees from certain conditions, and address barriers to formal sector employment. The report also addresses the need for protection from refoulement through due process in the refugee status determination process. They emphasize the recognition of their rights, collaboration among humanitarian organizations, UN agencies, NGOs, and local government departments, and the need for a collaborative approach to enable refugees to lead dignified lives with opportunities of their choosing (O'Loghlen & Bwami, 2018).

Entrepreneurship and participation in the informal sector emerge to be vital aspects for livelihood and refugee integration. Studies like Thompson's (2016) on Somali migrants in Gauteng, South Africa, reveal how refugees capitalize on "refugee capitalism" to create unique economic niches within townships. The economic success of Somalis in South Africa's townships is marked by entrepreneurship and upward mobility, underpinned by a blend of social and financial networks that leverage local infrastructures to create a distinct economic geography (Thompson, 2016). Similarly, Crush Tawodzera, McCordic, and Ramachandran (2017) illustrate refugees' dynamic engagement in South African urban areas' informal economies, highlighting their significant yet often overlooked economic contributions. The report challenges the misconception that refugee enclaves in the informal economy are stagnant or limited in scope. Enabled by South Africa's "self-settlement" policy, which allows free movement and living anywhere, refugees have established a noticeable presence in urban areas, such as Cape Town and Limpopo towns. Their involvement in the informal economy underscores underrecognized economic contributions (Crush, Tawodzera, McCordic, & Ramachandran, 2017). Crea et al. (2017) note that refugees leverage NGO support effectively, particularly through material assistance, to establish viable, profit-generating enterprises. This strategic utilization of NGO support for economic empowerment highlights the refugees' agency in overcoming adversity and integrating into local markets. Similarly, in cities like Kampala, New Delhi, and Johannesburg, refugees engage in informal employment and entrepreneurship, as described by Buscher (2013). These economic tactics not only provide a means of survival but also enable refugees to achieve a degree of autonomy and integration within their host communities.

CONCLUSION

The academic landscape surrounding urban refugees is vast and multidisciplinary, encompassing fields such as refugee and migration studies, ethnography, history, sociology, political science, urban studies, urban planning, human geography, and social psychology. Each discipline contributes a unique perspective to the understanding of urban refugee experiences. Given the vulnerabilities and disenfranchisement that urban refugees encounter, their experiences often intersect with themes from informal urbanism and the experiences of marginalized urban populations. My focus in this paper is specifically on how urban refugees navigate and claim contested urban spaces. The broader literature addresses the refugee crisis through various lenses, including humanitarian assistance (focusing on refugees' physical, material, and psychological needs), human rights (analyzing legal principles under international law), conflict (in contexts of civil wars and insurgencies), and anthropology (exploring social and cultural aspects of refugee life, including camp experiences, resettlement, and youth identity challenges). I have purposefully sifted through these diverse sources to distill our current understanding of how urban refugees navigate and claim urban space, as four strands of academic conversations.

The first area of debate addresses the conceptual tensions between postnational or denationalized citizenship and traditional citizenship models.Emerging forms of citizenship that transcend national boundaries could potentially redefine refugees' access to urban rights and services, contrasting sharply with conventional state-centric models. The second debate focuses on assimilation versus integration, emphasizing local integration as a potentially effective strategy for the inclusion of refugees in urban environments. The third debate delves into how refugees are portrayed, either stereotyped as passive victims and problems or as active agents of urbanism. The fourth debate addresses the dynamic between territorial stigma and identity management, investigating how refugees confront and navigate the stigmatization of their community spaces and manage and reframe their identities amidst socio-spatial exclusion.

Existing literature tends to focus on immediate or short-term strategies, often neglecting a thorough examination of the long-term impacts on both refugees and host communities. Çağlar and Schiller (2011) underscore the importance of locality in migration research, advocating for a nuanced understanding of the interplay between cities and migrants. This call to action highlights several key areas for future investigation, including the need for comparative studies exploring variations in refugee experiences, a focus on refugees as agents of urban change, an examination of transnational perspectives, and a shift towards comparative urban scholarship. Such scholarship aims to deepen our comprehension of urban refugee experiences and their impacts on host cities.

There is also a discernible dearth of detailed case studies offering a geographically diverse and comprehensive analysis of these spatial tactics across different cities in the Global South. The literature could benefit from adopting a more intersectional lens, delving into how factors such as gender, age, and ethnicity intersect with and influence spatial strategies. This approach promises a richer, more differentiated understanding of refugee populations' varied experiences and needs, facilitating more targeted and effective support strategies.

In light of these gaps, future research directions could include comparative studies across different urban settings in the Global South. Furthermore, research should focus on integrating refugee spatial tactics into urban planning and policy-making, while longitudinal research would be crucial for developing long-term solutions. Engaging refugee communities in the design and implementation of participatory action research is vital. Such participatory engagement would ensure that the research is grounded in the realities of refugee experiences and give them a voice in shaping policies and practices that directly affect their lives.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Toward Healthy Ageing: Unveiling Parameters to Construct a Well-Being Assessment Framework for Communal Senior Living in Kerala

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Abstract— Kerala has witnessed a pronounced increase in its elderly population, analogous to the global demographic shift, as evidenced by the latest census and United Nations reports. A significant proportion of its elderly populace consists of the 'young-old' and 'left behind elderly' subsets. This incipient demographic cohort is anticipated to remain active in the workforce, express technological proficiencies, and display heightened alignment with global perspectives. Furthermore, insights from Kerala Ageing Survey I and II substantiate the escalating demands in urban areas to develop a built environment that is conducive to 'Healthy Ageing'. The concept of 'Well-Being' through Healthy Ageing embodies a relatively recent approach stemming from gerontological studies in the 2000s. This notion emphasizes the imperative of amalgamating a multidimensional approach with Quality-Of-Life (QOL) parameters to ensure a holistic framework for elderly care and Well-Being. The State Government of Kerala has initiated various policies and strategies to incorporate Healthy Ageing principles into the communal senior living models mushrooming within the state. However, a comprehensive assessment framework that aligns with this inimitable set of requirements is yet to be established. This study aims to explicate the fundamental parameters for formulating an assessment framework specific to communal senior living, designed to promote Healthy Ageing and Well-Being within the unique context of Thrissur district, Kerala. Literature Review and semi-structured interviews were conducted to establish a comprehensive basis for this study and to understand the essential parameters influencing the needs, preferences, and expectations of the focus group. Qualitative Coding was conducted on the data obtained from the transcripts of stakeholder perspectives using Thematic analysis. Subsequently, the fundamental parameters were determined that can be applied to construct an assessment framework specific to the objectives of the study. The determined parameters were broadly categorized into four domains namely Physical environment, Social environment, Affordability, and Adaptability.

Keywords: Senior Living; Healthy Ageing; Quality-Of-Life (QOL); Assessment Parameters; Social Well-Being.

INTRODUCTION

Overview of the global and national demographic shift

The projections for 2050 indicate that 1 in every 6 people will be in the senior citizen category. The demographic shift which has primarily occurred in Europe and North America since the 1990s is projected to be more prominent in East, Southeast, and Western Asia by 2050 (Department of Economic and Social Affairs: Population Division, 2020).

The demographic shift in India is attributed to three dominant factors, i.e. Declining fertility rates, Declining infant mortality rates, and increased life expectancy rates (Agarwal et al., 2016). The population share of the elderly at the national level is projected to increase from 10.1% (2021) to 15% (2036). Significant interstate variation in elderly population levels and growth has been witnessed. Southern states, Himachal Pradesh, and Punjab demonstrate a higher elderly share than the national average (United Nations Population Fund, 2023).

Specifics of the elderly population increase in Kerala

Kerala shows the highest life expectancy rates in India at 72.5 (males) and 77.8 (females). The old-age dependency ratio is 20% and the work participation rate is 25%. The proportion of the elderly population is distributed equally in urban and rural areas (State Planning Board, 2020; United Nations Population Fund, 2017). The historical, economic, political, and social triggers that contributed to the greying nature of the state include the breakdown of the joint family system, the abolition of the 'Marumakkathayam' system, social and land reforms, shift towards a non-agrarian economy, high literacy rates, high internal and external migration of youth, low fertility and mortality rates and high human development Index (Department of Economics & Statistics, 2005).

The total population of elderly is highest in Ernakulam and Thrissur District accounting for 62% of old age homes. Thrissur district is the 'backbone' of external emigration and houses a significant proportion of 'left behind elderly'. In 2017 the district panchayat of Thrissur declared to upgrade it into an 'Elderly Friendly district'. Hence, this study focuses on Thrissur district. (Mathew, 2020; Rajan et al., 2020; Sujathan, 2012; Zachariah et al., 2001).

METHODOLOGY

The study was conducted in three major parts: Literature Review, Drafting of a survey questionnaire, and semi-structured interview.

LITERATURE REVIEW

Implication of built environment on Healthy Ageing and Well-Being

The definition of 'Elderly' is vague and subjective. Social gerontologists define it using four domains: chronological, biological, social, and psychological (Novak, 2018; Philips et al., 2010). Initial studies were predominated chronologically while biomedical parameters were incorporated in the late 1990s (Andersson, 2011; Bowling and Dieppe, 2005; Fagerström and Aartsen, 2013). Psychosocial approaches centring on life satisfaction, social engagement, and overall well-being rose in the 2000s (Orimo et al., 2006). The evolution of multidimensional definition and subset categorization within the elderly group emerged in the 2010s incorporating the subject's perceptions and interdisciplinary considerations (Rajan et al., 2020; Little, 2014; da Silva and Baptista, 2016; Bowling and Stenner, 2011).

The evolution of the academic discourse translated into the design of the built environment as well. The architecture of the built environment began to be shaped to cater to the diverse needs of the elderly population (Mitchell and Kemp, 2000). Senior housing evolved from institutionalized care in the 1700s, in North America and Europe. The 19th century marked the beginning of community aging facilities in Europe embracing alternative models. The 21st century witnessed a demand for innovative and compassionate senior living, emphasizing autonomy (Anderson 2011). In the Asia-Pacific region, aging in place was prevalent, later shifting toward community aging facilities along with the introduction of guidelines for elderly care. Contemporary senior living worldwide prioritizes choice, variety, adaptability, and control, addressing specific concerns like health and social connections (Perkins Eastman, 2019).

Insights from Kerala Ageing Survey I and II

Amongst the elderly population of Kerala, 58% of the elderly belong to the 'young-old' subsection. The percentage of elders living alone or with a partner or spouse has increased to 27.2% by 2013. Between 2014 - 2018 an increase of 69% was reported in the number of residents checking into old age homes. The 'young-old' subsection constitutes the highest proportion of the occupants in old-age homes, i.e. 48%. Primary reasons stated include a preference for 'end of life' living with people of similar age groups, isolation, loneliness, and insecurity. The majority of this subsection is reported to be having higher education, living alone or with their spouses, and capable of performing activities of daily life (ADL) with little or no assistance. However, a considerable number of elderly in this subsection suffer from two or more chronic diseases and feel they need diet care, exercise routines, and mental health services.

Government Initiatives in Promoting Healthy Ageing

The state-level schemes are observed to fall under Healthcare, Financial Security, Legal Advocacy and Tribunals, Social Justice and Empowerment, Housing, and Residency. The Social Justice Department of Kerala proposed strategies following WHO's declaration of the 'Decade of Healthy Aging', and align with the principles of healthy aging by WHO i.e. Ability to meet basic needs, Learning, growth and decision making, mobility, contribution to society, and Relationship building. The state identifies the demographic makeup of its elderly and the proposals are aimed at incorporating the elderly as an important human resource in the society.

Need for a Comprehensive Assessment Framework

The Department of Social Justice oversees 16 old-age homes. However, 623 private care centres have been registered with the Orphanage Control Board. The data reveals a consistent rise in the number of residents within these facilities amounting to 30105 in 2023. Simultaneously, in response to the growing market, multiple communal living models are mushrooming within the state such as retirement communities, Elderly apartment complexes, and retirement retreats.

Following the drafting of the State Old Age Policy in 2005, the 'Manual of Old Age Homes - 2016', 'Kerala Municipality Building Rules, 2019' and 'Kerala Panchayat Building Rules,2019' were developed with a focus on design and operations. At the national level, the National Building Code of India 2016, and the 'Model Guidelines for Development and Regulation of Retirement Homes' by the Ministry of Housing and Urban Affairs (MoHUA), outline a specified set of guidelines for senior living. However, they serve more as design standards and lack applicability for assessing existing facilities. Despite extensive literature exploring the impact of built environments on the elderly, there is a notable lack in the assessment process.

Tailoring an assessment framework for Kerala is imperative due to the unique context of the region. Contextual specificity and integration of healthy aging principles are crucial so that the framework promotes overall well-being and aligns with the governmental policies of the state. Adopting a multidimensional approach concentrating on community integration will enable a comprehensive evaluation, considering the built environment, social, and economic aspects. The increasing young-old and left-behind elderly subsets emphasize the need to cater to their specific needs, especially employability enhancement.

Survey

Using the reviewed literature as a foundation, a meticulous questionnaire was developed in consultation with experts from fields encompassing Gerontology, Public Health, Architecture, Economy, and Sociology. The semi-structured questionnaire contained 33 items including dichotomous questions, multiple-choice questions, and open-ended inquiries. It aimed to capture the quantitative data and glean the needs and preferences of the user group.

The target user group was individuals aged 60-70, representing the "young-old" subsection within Thrissur district, Kerala. The sample included an equal balance of both genders, encompassing individuals from various strata of society and residing in different types of communal senior living facilities. The research employed the normal distribution approach with finite population correction, factoring in a 90% confidence level and a 10% confidence interval. The resulting sample size (n = 68) was rounded off to a practical size of 70.

Thematic Analysis

The semi-structured interview of the selected sample was conducted in English and Malayalam. Their responses were collated and transcribed in English for the thematic analysis and qualitative data analysis software NVivo 14.23.2 (46) was utilised. Recurrent patterns within the dataset were identified into different codes, which were systematically mapped under derived themes and then related to parameters gleaned from the literature review.

RESULTS AND DISCUSSION

The discussion section served as the nexus where the outcomes of the thematic analysis were synthesized with the identified domains and subdomains essential for assessing communal senior living models. The thematic analysis illuminated key parameters and provided context-specific nuances that informed the understanding of communal senior living within the target community.

Parameters Identified to create an assessment framework can be classified under 4 major domains: Physical Environment, Social Environment, Affordability, and Adaptability.

Physical Environment marks a major influence on the elderly by shaping accessibility, safety, and comfort in private and shared spaces, impacting overall well-being (Perkins et al., 2013; Perkins Eastman, 2019). Infrastructure, Green and sustainable practices, and climate-responsive design have been incorporated in subdomains to ensure a thorough assessment of a healthy and adaptable living environment for the elderly.

Social Environment equally influences the well-being of the elderly. It is instrumental in fostering community integration. Diverse cultural and recreational activities, a supportive built environment, inclusive approaches, and comprehensive health and wellness-oriented practices are essential to create a conducive social environment.

The affordability domain of senior living encompasses various financial aspects. It also involves exploring ownership alternatives and funding options to ensure flexibility. It must aim to be inclusive, accommodating individuals from different economic brackets. Additionally, alignment with governmental schemes, NGOs, and access to subsidies and incentives further contribute to ensuring economic accessibility for the residents. The adaptability domain has a multifaceted approach. It includes options for modification in the built environment, social environment, and personal growth of users. Technology integration and customization options of built environments and services help promote independence, safety, and choice amongst the users. Additionally, a focus on skill development and employability enhancement for elderly residents cater to the development of their self-esteem and autonomy (Perkins Eastman, 2019).

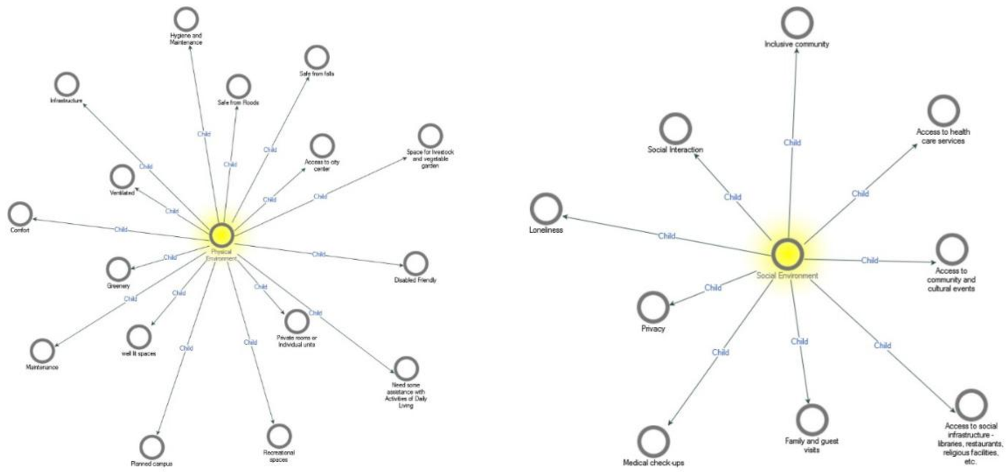

Figure 1: Mapping of codes from Thematic Analysis – Physical Environment and Social Environment

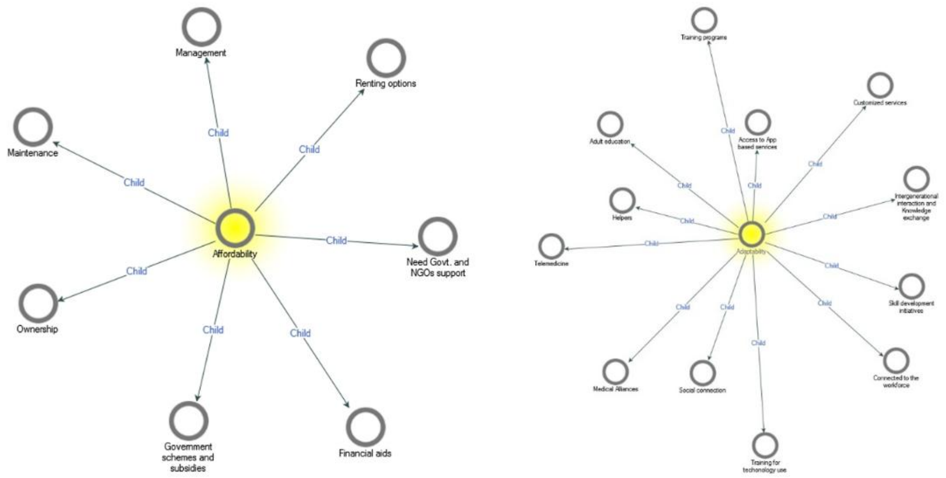

Figure. 2: Mapping of codes from Thematic Analysis – Affordability and Adaptability

CONCLUSIONS

The study aimed to identify the parameters that can aid the formulation of a comprehensive assessment framework for communal senior living facilities within Kerala. The parameters were delineated with a focus on healthy aging and well-being requirements, stakeholder perspectives, and expert opinions. Four influential domains were identified using a literature review. Further subdomains and indicators were gleaned from the insights of survey and semi-structured interviews. Thematic Analysis helped in refining the insights into the development of a comprehensive list of parameters.

The findings of the study lay the groundwork for the creation of a comprehensive assessment framework that aligns with the principles of Healthy Aging while meeting the specific demands of the unique demographic landscape of Kerala. The scope includes the establishment of an assessment framework for communal senior living integrating the contextual specificity of Kerala, with the potential to inform policy-making decisions, inform the architectural design process, and promote the overall well-being of the target user group. Phase II of this study is aimed at the validation and refinement of the framework through field testing and feedback evaluation.

However, the study currently focuses on a specific demographic subset, within the Thrissur district and encompasses only communal senior living facilities. Further research could explore the inclusion of a wider range of subsets, regional contexts, and models of residence.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Design Quality Indicators to Assess School-Built Environment

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Abstract— The National Education Policy 2020 has initiated a new era of learning in India and thus needs to rethink the design quality of the built environment of schools. Objective assessment of the quality of design is a complex issue in any built environment. In India, several standards and codes and different building environment assessment methods are used to evaluate different aspects of design. However, an integrated framework that assesses the quality of the design objectively for the built environment is yet to be formulated. So far, generally, design quality is a matter of perception and subjectivity of the individual. An extensive literature review identifies the need for a comprehensive design quality assessment framework. A theoretical background was established based on a review of several international and national standards, codes, and best practices. The Design Quality Indicator (DQI) of the Construction Industry Council, UK has been used as the basis for the formulation of the quality assessment framework in the Indian context. A total of forty-four scholastic papers addressing the quality of school building design were selected for consideration. To identify the factors of the design quality, a questionnaire with 122 questions was created and a three-level Delphi was conducted online mode using a Likert scale. A total of 68 responses were considered for the relative relevance of each question was determined by calculating its average RII, and following three rounds of Delphi, the total number of questions was reduced to 110. A relative priority matrix was created using the "Required" (more than 4.5 RII), "Desired" (four to 4.5), and "Inspired" (less than 4) qualities. These 110 factors are run through Confirmatory Factor Analysis to test the DQI's factor structure to increase the framework's reliability, accuracy, and simplicity. Which reduces the factors from 110 to 65. Finally, an AHP has been conducted with the help of 36 experts in the field of architecture to conduct a pairwise weighing survey to generate an objective framework to assess the design quality of the school buildings in the Indian context.

Keywords: Design quality indicators, School built environment, Delphi technique, Analytical Hierarchy Process, and Confirmatory factor analysis.

INTRODUCTION

The National Education Mission (Samagra Shiksha Abhiyan) of India launched in 2018 is a programme for school education from preschool to class 12 (K12). It was allocated a budget of ₹385.72 billion in the 2019 Interim Union Budget of India. There is an increase in the budget for school education in India from 2021-22 to 2024-25 by 46 per cent (refer to Table 1).

There has been an overall increase of ₹12,024 crore (19.56%) in the Budget Allocation of Department of School Education and Literacy in the FY 2024-25 from RE 2023-24. It is clear from Table 1 that the investment in the education sector has increased, therefore, there is a need for physical spaces to make this investment work efficiently. The Sustainable Development Goal 4 (SDG4) mandates the provision of 'equitable' and 'inclusive' quality education for all by 2030 and it is UNESCO's (2020) global education agenda. It, therefore, demands high design quality of school-built environment since it plays a vital role in shaping the students' behaviours, health and well-being and their educational success (Cassidy, 1997). Additionally, an evaluation of the design of the existing schools must be conducted to determine the standard of the spaces that have been established.

Table 1. Budget allocation in the education sector in India, 2023- 24 (Reference: Expenditure budget 2021- 22 & Notes on Demands for Grants, 2023-2024, 2024-25, (https://www.indiabudget.gov.in/) and https://pib.gov.in/ as accessed on 31.05.2024

Notes on Demands for Grants, 2023-2024			
Budget 2022-2023	Revised 2022-2023	Budget 2023-2024	Budget 2024-2025
63,449	59,052	68,804	73,498
All figures are in Crore			

Therefore, to assess the design quality a framework is required which will quantify the appropriateness of the design of school buildings in India and make a DQI framework for the future design of the schools.

Quality is one of the triple attributes in any project; the other two are time and cost. The value of any project is dependent chiefly on these three pillars (Refer to Figure 1). Project Management Institute defines project value as the value it creates for its stakeholders in terms of effectiveness and satisfaction (Lechler, 2010). The success of any project is primarily a balancing act of managing these three attributes. While there are measuring tools for both time and cost, quality is not assessed objectively. Cambridge Dictionary defines quality as "of a high standard" or "the degree of excellence of something, often a high degree of it". The Oxford Dictionary defines quality as "The standard of something as measured against other things of a similar kind".

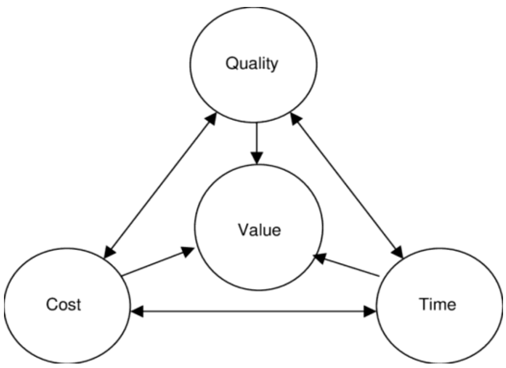

Figure 1. Value as a function of time, cost, and quality, source: author

The value of design to its user can be considered as the quality of design. The design could be for any product, service, system, or experience. The design quality is a function of any combination of usability, performance, aesthetics, reliability, predictability, stability, consistency, safety, and security (Amanda et al, 2018). Assessing design quality is still in a very elementary stage in developing countries like India, though it significantly impacts the satisfaction of the end users. The building is a product of design, and the quality of the building depends on the quality of the design. ISO 9000 (2015) on Total Quality Management includes customer satisfaction in the organization's objectives. In the case of buildings, the end users are the primary customers of the product. The quality of design improves the efficiency of the building. Assessing the design quality in different stages of the project life cycle is essential. The quality can be evaluated during the briefing, predesign, construction, and pre-and post-occupancy stages. Also, all the factors in the design might not have the same weightage on the assessment scale (Cardellino et al, 2010).

Review of literature and theoretical framework

The idiosyncrasy of the architectural design process is that it is a fusion of creative and scientific infusion resulting in the architectural potential for the adaptation of the environment to identified human purposes (Herbert, 1966). As per the Domain Theory, architectural design is both the process and the product, which is made up of several phases and phases consisting of parallel and serial activities (Bax et al, 2001). With the invention of new technology, architectural design is becoming more complex day by day. A participated design approach requires the will and competence of each team member, including architects, engineers, urban planners, and contractors. The procurement process for the building has become complicated due to various factors like the quality of projects, cost to the client, and time of completion. From traditional design-bid-build through design-build and management system of procurement, to public-private partnership the procurement process has transformed a great deal (Greenhalgh B., & Squires G., 2011). ISO 9001: 2015 promotes the application of a process-based approach for developing, implementing, and upgrading the effectiveness of a quality management system to raise client satisfaction. Total quality management (TQM) is a management theory whose goal is to increase a company's capacity to provide quality to its clients on a foundation of continuous improvement. This applies to both the product and the services. As a building is a product of design total quality management applies to building design as well. Indicators of design quality vary with the location of buildings, building typology, types of users etc. To study the factors influencing the design quality of school buildings in the context of India, it is important to know various building environment assessment tools used worldwide and specifically in India. To establish the theoretical background of the design quality assessment of school buildings, various codes and standards, like, the National Building Code of India- 2016, IS 8827 – 1978: Recommendations for basic requirements for school buildings), Compendium of Architectural Norms & Guidelines for Educational Institutions by CPWD, BS7850 – 1: 1992, British Standard were studied and compared. Various design quality assessment tools have been produced and followed in various countries for more than a decade now. While the Housing Quality Indicator (HQI) of the UK, 'Building for Life' by CABE in the UK, and the Home Quality Mark by BREEAM are used specifically for residential buildings, the Design Quality Indicator (DQI) of the United Kingdom by the Construction Industry Council provides separate indicators for school buildings along with other typologies. The quality criteria for Indian schools were finalized from the criteria mentioned in the bylaws, standards, and quality indicators. Along with that a thorough literature survey of 177 research papers has been done on the topics mentioned below,

Architectural design process: 45

School Design: 35

Design quality indicators: 47

Post-occupancy evaluation: 50

The study of the above literature formed the theoretical background and the scoping review. Then the literature survey was narrowed down to 44 research articles discussing the school's design quality. Out of those 44 research papers, 13 papers were selected to identify the categories and the criteria of design quality indicators. Those criteria were used to formulate the questionnaire for the expert survey

Significant findings from the literature review

Among the 44 research papers on design quality and school design, 13 have been selected, which have listed down all the criteria from DQI of the Construction Industry Council, UK that make a project successful and validated them involving the project stakeholders in different stages of projects. The DQI criteria, namely Use, Access, Space, Performance, Engineering Systems, Construction, Internal Environment, Form and materials, Character and innovation, Urban and Social Integration, and their various attributes are mapped through these 13 research papers to understand the frequency of occurrences of different indicators also the inclusion of quality indicators in each literature (refer to Table 5 in appendix 1). Out of 44 indicators of DQI, individual research papers covered as low as three to a maximum of twenty-three indicators and/or attributes. A higher number of indicators included in the assessment framework means a high success rate and accuracy of the design assessment, which brings stakeholders' involvement and satisfaction to the project, making a project a delight.

On the other hand, the frequency justifies the importance of one indicator in the entire list and people's acceptance of the indicator while assessing the design quality.

METHODOLOGY

Design quality management is a complex issue in any construction project. In India, several standards and codes like the National Building Code 2016, several BIS standards and different building environment assessment methods are used to judge different design aspects. However, no tool or method has been developed yet to assess design quality objectively. As a result, design quality has remained a matter of perception of individuals and subjectivity. As there is a need for a new age education system in India and the Government has been allocating more budget towards it (refer to table 1), there is a need for physical space to make this investment work efficiently. Further, these schools would be functionally efficient if the design quality is good and also the increased budget towards built facility should be justified. Therefore, to assess the design quality, a framework is required to quantify the appropriateness of the design of school buildings in India and make a DQI framework for the future design of the schools.

Research objectives

To review the state-of-the-art design quality assessment methods and classify them based on their application and domain.

To review building environment assessment methods and relevant Indian codes and standards pertinent to the design of school buildings.

To identify different applicable categories and criteria to form the dimensions of the design quality assessment methods by participation and consensus of experts in the design field.

To determine an intermediate weightage of all the criteria and their relative importance in determining the design quality of schools in India.

Scope and limitations

The design requirements vary depending on the type of building. As a result, the evaluation tool will vary depending on the type of building. The design assessment of the Indian urban education sector will be the main emphasis of this study. In India, the education sector is growing. As previously mentioned, there is a great need for well-designed schools in India because of advancements in teaching methods. The outdated infrastructure is unable to keep up with the rapid advancement of information technology-based teaching practices. The spatial requirements in the school buildings are also changing. In this research, the author will develop a framework to assess the design criteria which will be applied on three case study schools. The schools selected as case studies could be one Government school, one Government school and one private school. This variety of types of schools will provide a wide range of assessment criteria. However, the study will be limited to the Indian urban context only.

Significance of the research

Traditionally, architectural design used to be handled in a more repetitive, consistent, and intuitive manner (RIBA, 2020). With the altering disposition of clients' team, design team, and project team the design of projects is now a more complex issue and requires to be dealt with more understanding. Throughout the project's life cycle, there are numerous stakeholders whose connections with the project may or may not be contractual. Managing and responding to numerous types of opinions coming from various stakeholders at different stages could be complex. A systematic involvement of various project stakeholders can minimize the complexity. This collaborative design process can bridge the gap between the users' aspirations and the designer's imagination (Coughlan & Macredie, 2002). Studies have established that inadequate stakeholder management is one of many causes of project failure (McManus, 2008). Conflicts between users, large numbers of users, lack of users' participation, non-willing users, and unrealistic expectations are some of the causes (Taherdoost, Keshavarzsaleh, 2015) that lead to project failure. Therefore, there is a need to involve project stakeholders systematically throughout the project lifecycle to assess the design quality. Till today, assessing design quality remains a subjective process which highly depends on the experience of the individual. Many countries have already started to assess design objectively. In the United Kingdom, the Construction Industry Council developed the Design Quality Indicator tool and has already applied it to 1400 projects worldwide over 19 years since 2003 till date. In India, there is no such single assessment tool available as of now, which evaluates any project holistically. The

buildings which are designed as per the local and national byelaws and codes, sustainability, and energy conservation guidelines, only cater to the fundamental quality aspects. However, for the design quality to reach the value added or excellence stature, there is a need to develop a single assessment tool which could objectively quantify the architectural design quality.

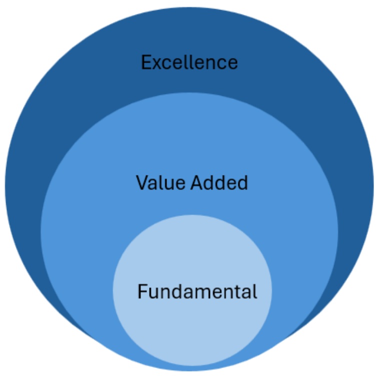

Figure2. Quality of design (Fundamental, Value added and excellence). Source: Construction Industry Council of UK, 2003

Research design

To meet the objectives already stated, the following steps are to be taken in this research.

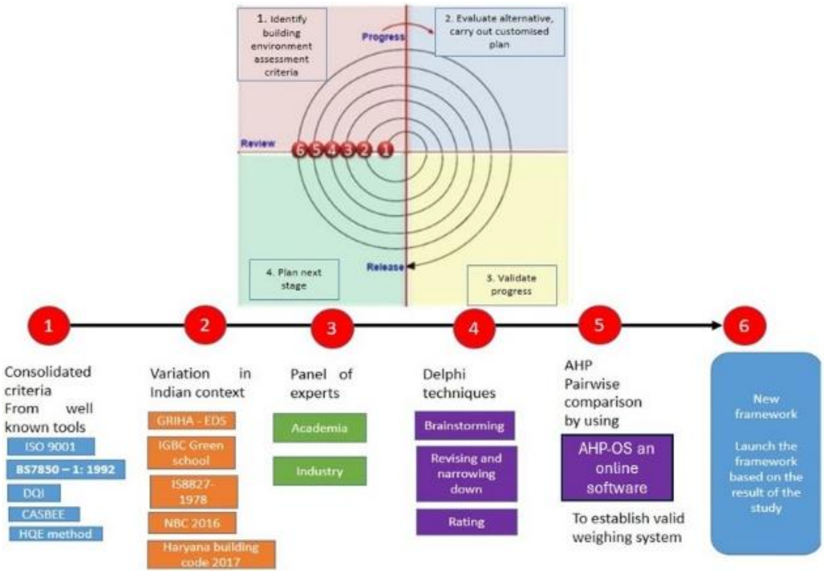

Figure 3. The theoretical framework of Design quality Indicator development, source: author

Delphi data collection process

A survey questionnaire was formed which includes all the questions from DQI meant for school. Following the same format of DQI of the United Kingdom an expert survey was conducted with experts from industry and academia. The panel consists of the faculty of architecture, practising architects, project managers, school principal, and retired NCERT personnel. The intent of doing the expert survey was to validate the questionnaire consisting of design quality criteria being followed in the UK, and in the Indian context and to determine the relative importance of the criteria.

The relative importance index from the delphi technique

The questionnaire consists of 122 questions, representing the criteria for design quality were divided into 11 subgroups. The 10 subgroups consisting of 122 questions, namely Use, Access, space, building performance, building engineering services, Construction, Internal environment, Forms and materials, Character and innovation, and Urban and social integration were taken from DQI introduced by the Construction Industry Council, UK (Gann, 2003). The responses are based on a Likert scale of zero to six. Where 'zero' is "not applicable" and six is "strongly agree". The first level of Delphi consists of 36 respondents. The panel consists of faculty of architecture, practising architects, project managers, school principal, and retired NCERT personnel and their experience ranged from 7 years to 35 years. The experts were selected based on their expertise in the field of education, and architecture. The Delphi questionnaire was sent to the experts with the help of Google Forms and telephonic discussions were conducted for clarifications of the questions. The questions asked in the first Delphi which scored a RII (discussed in 3.6.1) lesser than 4.0 were discarded and the total number of the criteria came down from 122 to 113. Then the second level of Delphi was carried out by following the same process as followed in the first Delphi. The respondents of the first Delphi were communicated through email for their availability and willingness for the second level of Delphi. This time the survey was answered by 25 respondents. A third level Delphi was conducted involving 7 users namely school administrators, and teachers. The third level Delphi was paper-based and conducted by meeting the respondents in person by the author.

Factor reduction and scale development

The total responses of 68 (36+25+7) respondents were taken into consideration in three-level Delphi while calculating the RII of the criteria. The RII is given as

$$RII = \Sigma W / (A*N)$$

Where W is the weighting given to each question by the respondents (ranging from 1 to 6), A is the highest weight (i.e. 6 in this case), and N is the total number of respondents. The 'not applicable' criteria, as it was assigned 'zero' do not have any bearing on the calculation of the RII. The higher the value of RII, the more important the criteria in measuring design quality. The importance level of RII is given in Table 2

Table 2: Importance level from RII

Level	Score
High (H)	0.8<RII<1.0
High- Medium (H-M)	0.6<RII<0.8
Medium (M)	0.4<RII<0.6
Medium - Low (M-L)	0.2<RII<0.4
Low (L)	0.0<RII<0.2

The final RII showed a high value for most of the criteria and High – Medium for only 4 criteria namely

1. There should be sufficient car parking
2. The building and site layout should cater for cyclists
3. The building will cater for the needs of people with impaired sight
4. The boundary treatment is suitable

It follows that every criterion selected to determine the level of school building design excellence is crucial and necessary.

A category ranking was obtained by taking an average of the weights of all the criteria coming under a category. Each criterion was assigned with a credit of either 1, 2, or 3 based on the final weightage calculated after three levels of Delphi. The distribution of the credits was as follows

Table 3: Credit distribution based on weightage

Weightage	Credit
5.5 to 6	3
5 to 5.5	2
4.5 to 5	1

Factor reduction through factor analysis and reliability test of variables

Though the variables of DQI are established in the public domain, however, a Confirmatory Factor Analysis was conducted to purify the list and reduce the number of variables which should be suitable for school buildings in the Indian context. The objective would be to determine the degree to which the factors and assessment items associated with each dimension account for the variability in the responses in that dimension. The analysis that is produced facilitates to average or aggregate of all of the pertinent measurement data items corresponding to each relevant factor. It extracted 65 variables from 122 total variables based on the correlation matrix. The rotation method followed in this analysis is Varimax with Kaiser Normalization which decreases the standard errors of the loadings for the variables with small commonalities. All these 65 variables were then run through a reliability analysis. The reliability test evaluates the consistency between various measures of a variable. The Cronbach's Alpha test was applied here. The value of Cronbach Alpha thus received is given in Table 4.

Table 4: Experts' factor analysis and reliability

Functionality	Number of factors (eigenvalue >1)	19
	Variance explained	79.382%
	Cronbach's Alpha Based on Standardized Items	0.929
	KMO	0.565
Build Quality	Number of factors (eigenvalue >1)	17
	Variance explained	81.266 %
	Cronbach's Alpha Based on Standardized Items	0.963
	KMO	0.682
Impact	Number of factors (eigenvalue >1)	16
	Variance explained	76.591%
	Cronbach's Alpha Based on Standardized Items	0.947
	KMO	0.771

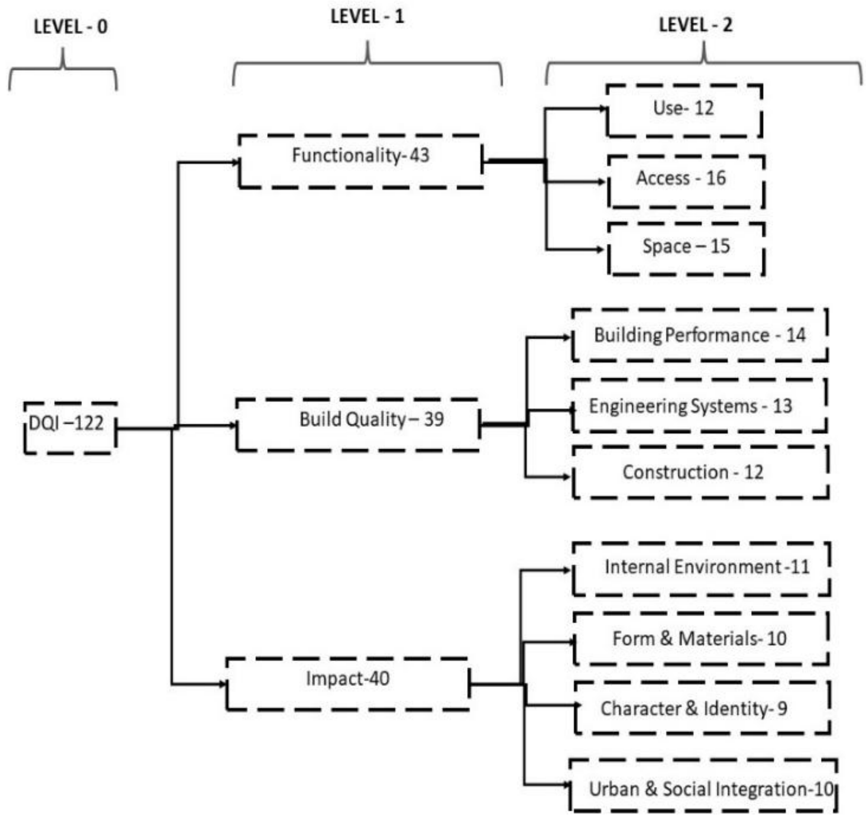

Figure 4: Revised DQI structure using original factors and dimensions.

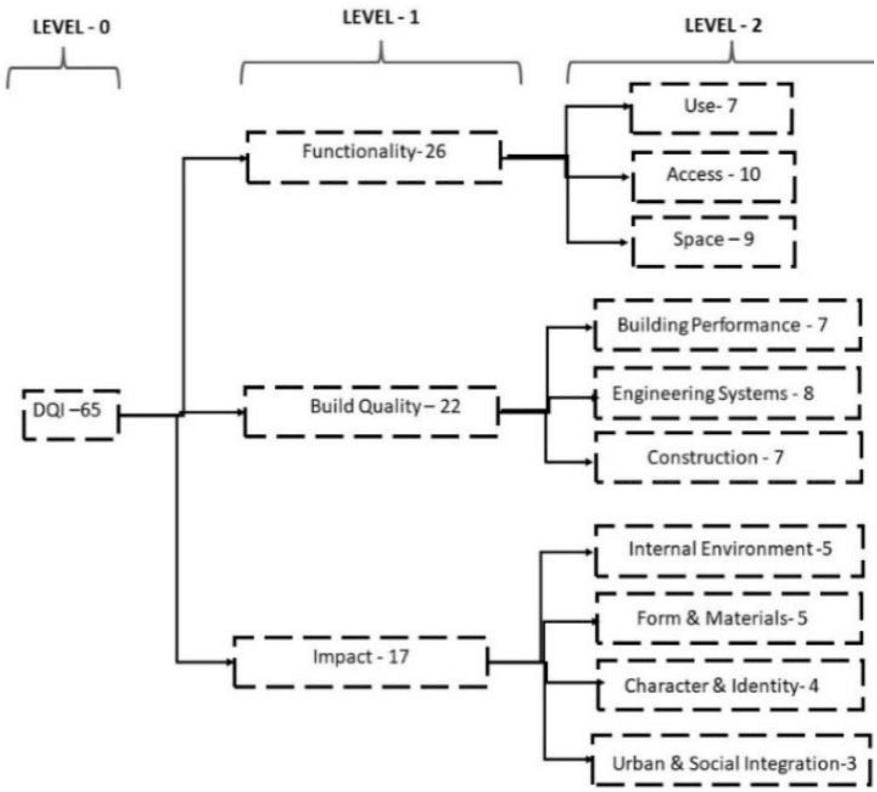

Figure 5: Revised DQI structure using original factors and reduced dimensions

Analytical hierarchy process

Thomas L. Saaty in the 1970s pioneered the use of AHP, a multi-criteria decision-making (MCDM) strategy (Harputlugđl, 2009). It makes use of a multi-level hierarchical structure for its goals, decision-makers, criteria, and alternatives. A series of pairwise comparisons is used to get the relevant data. These comparisons are used to determine the relative performance measurements of the alternatives about each choice criterion as well as the weighted significance ratings of the decision criteria. It offers a way to increase consistency if the comparisons are not entirely accurate (Saaty 1980, Harputlugil et al. 2009).

36 experts from the field of architecture, construction and education were requested to fill out an AHP format prepared with the help of Google form. The first two levels of criteria were considered for AHP in this stage (refer to Figure 3). The experts were asked to provide relative importance on a scale of 1 to 9 as mentioned in AHP (Satty, 1970).

Based on the responses of the experts a decision hierarchy was generated by the online software where the consistency ratio was accepted below 10 percent. Table 5 shows the category-wise weighing coefficients of the variables.

Table 5. Category ranking, factors, credits, and weighing coefficient of variables

Sl. No.	Variable	Overall ranking of category	Number of factors	Number of Credits	Weighing coefficient from AHP
		Mean			
A1	Use	5.237	7	12	0.2180
A2	Access	5.069	10	18	0.1069
A3	Space	5.389	9	22	0.1465
B1	Building Performance	5.394	7	16	0.1937
B2	Building Engineering Systems	5.924	8	18	0.0673
B3	Construction	5.421	7	15	0.0519
C1	Internal Environment	5.381	5	14	0.1200
C2	Forms and material	5.327	5	12	0.0477
C3	Character and Innovation	5.218	4	8	0.0270
C4	Urban and social integration	5.107	3	5	0.0203
	Total		65	140	1.0

For any project design design quality can be achieved by the the following formula:

Design Quality Indicator = Σ (Achieved credit / Available Credits - Not applicable credits) x weighing Co efficient x 100

CONCLUSION

The variable reduction was done through three stages Delphi and confirmatory factor analysis. The confirmatory factor analysis has purified the numbers of variables in a most parsimonious way. It has reduced the number of factors from 122 to 65. These 65 variables have been selected for the formulation of the framework. A reliability analysis has also been conducted on the variables separately for functionality, build quality and access. The value of Cronbach's Alpha for reliability ranges between 0 and 1. The more it is close to 1, more higher the reliability. The value of Alpha for functionality, Build quality, and impact are 0.929, 0.963, and 0.947 respectively (refer to Table 4). Therefore we can conclude that the variables taken under the factors are highly reliable and create a consistent data set for the framework. All the 110 variables distributed under functionality(43), Build quality (39) and impact (40) have been considered for the reliability test and no variable has been removed by the software. However, as it was extracted by the factor analysis, 65 factors were finally retained to create the framework. The Analytical Hierarchy Process helped in a pairwise comparison and helped achieve the weighting coefficient to normalise the result of Delphi. As shown in Table 5, the maximum credit calculated for "space" is 22 whereas the global weightage of the same is 0.1465. Similarly, weightage was assigned for all the factors along with the credits. The total achievable credits thus calculated is 140. Therefore the design Quality Indicators of any project can be achieved by summing the total achieved credits upon the available credits of the project and multiplying it with the weighting coefficient.

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Appendix 1

Table 6: frequency of occurrences of different indicators in the literature

	Indicators	(Gibson et al., 2003)	(Zemke, et al., 2008)	Ruddock et al., 2009)	(Cardellino et al., 2010)	(Giddings et al.,	(Deliberador et al., 2011)	(Giddings et al., 2012)	(Harputlugil et al., 2014)	(Hatem et al., 2014)	(Suratkon, 2016)	(Gordon and Ross 2017)	(Zemke et al.,2018)	(Eilouti, 2020)	Frequency
A	Functionality														
A1	Space														3
1	Space size and proportions														3
2	Fit for purpose														4
3	Relation with spaces														3
4	Privacy														3
5	Circulation														8
6	Open space														7
7	Settlement														
A2	Access														10
1	Local access/ access to public transport														3
2	Interior access														2
3	Inter-unit access														1
4	Universal accessibility														1
5	Parking														3
6	Layout														6

	Indicators	(Gibson et al., 2003)	(Zemke, et al., 2008)	Ruddock et al., 2009)	(Cardellino et al., 2010)	(Giddings et al.,	(Deliberador et al., 2011)	(Giddings et al., 2012)	(Harputlugil et al., 2014)	(Hatem et al., 2014)	(Suratkon, 2016)	(Gordon and Rose 2017)	(Zemke et al.,2018)	(Eilouti, 2020)	Frequency
A3	Use														2
1	Fit for functionality														3
2	Flexibility														6
3	Adaptability														5
B	Build Quality														1
B1	Engineering Systems														4
1	Natural Lighting														7
2	Artificial Lighting														3
3	Natural ventilation														3
4	Artificial ventilation (HVAC)														4
5	Electrical systems-Automation														4
6	Security														3
7	Acoustic (Noise control)														7
B2	Construction														4
1	Durability														3
2	Code Compliance														2
3	Structural elements and systems														6
4	Finishings														7
B3	Building Performance														
1	Easy to maintain														2
2	Easy to clean														1
3	Energy Performance														5
C	Impact														
C1	Internal Environment														
1	Easy-to-understand layout														8
2	Indoor Air Quality														3
3	Visual effect / Visual														2

	Indicators	(Gibson et al., 2003)	(Zemke, et al., 2008)	Ruddock et al., 2009)	(Cardellino et al., 2010)	(Giddings et al.,	(Deliberador et al., 2011)	(Giddings et al., 2012)	(Harputlugil et al., 2014)	(Hatem et al., 2014)	(Suratkon, 2016)	(Gordon and Pasa 2017)	(Zemke et al.,2018)	(Eilouti, 2020)	Frequency
	comfort														
4	Thermal comfort/ Thermal adaptation														2
5	Security and safety														6
C2	Form and Materials														
1	Colour and texture														5
2	Form														7
3	Material														4
C3	Character and innovation														
1	Aesthetics														3
2	Context														7
3	Age														1
4	Identity and character														3
5	Human Factors and Social Interaction														1
C4	Urban and social integration														5
1	Connection with the local community														2
2	Neighbourhood quality														6
3	Social and economic regeneration														6
	Total No. of the indicator from DQI	14	23	14	7	3	16	12	21	6	15	11	22	12	

Physical Environment and Children's Wellbeing; A Correlational Study of a Slum Community in Pune, India

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Abstract— Rapid urbanisation in India has led to the emergence of slums. Slums are surrounded by multiple issues concerning the socio-physical environment. The physical environment of slums and its attributes of overcrowding, poor sanitation, lack of basic services, and substandard housing pose a risk to the wellbeing of the inhabitants. Further, many children living in slums are exposed to issues afflicting the physical environment. The urban slum fabric consists of dense residential units inhabited by such underprivileged children and their families. Multiple studies have reported that substandard housing and overcrowding are the key determinants of socio-physical wellbeing. They not only aggravate the risk of diseases but also amplify issues related to mental health due to lack of space. This study examines the impact of the slum physical environment of Dapodi on the wellbeing of the children. The study employs a mixed method of research with a sample size of 32 children between the ages 13 and 18 living in the slums of Dapodi in Pune city, based on the central limit theorem. The quantitative data was collected using a two-pronged approach; the standardised Stirling Children's Wellbeing scale to understand the wellbeing of the children; and a Likert based questionnaire survey to understand the perspectives of slum children towards their physical environment. Qualitative data was collected in the form of a cognitive mapping exercise to understand specific locales of the physical environment which the children frequented for interactions, given the socio-spatial constraints. A correlational analysis to explore the impact of the physical environment on children's wellbeing was done using Pearson's correlation. The research examined whether the lack of community infrastructure influenced the overall wellbeing of children residing in the slums of Dapodi in Pune city.

Keywords: Built Environment; Deprived Children; Well-being; Slums; Perception Studies

INTRODUCTION

The Urban slums are characterised by their lack of basic infrastructure and issues related to overcrowding. Slums are a growing concern not only in large cites but also in the smaller towns of India. At present, 377.1 million of India's population is living in urban areas, out of which 17.4 percent are residing in slums (Census of India, 2011). Pune, the 'cultural capital' of Maharashtra has witnessed a population growth of 7.8 percent from 2001-11 (Census of India, 2011). Pune having emerged as a metropolitan city has been experiencing major challenges with respect to slums settlements. The city has attracted thousands of immigrants due to various economic activities and compelled them to live in slums due to poor affordability (Mundhe, 2019).

As per a survey by the National Sample Survey office (NSSO) in the year 2012, around 28 percent of urban children have grappled slum conditions in India. Inspite of the physical environment of slums posing challenges to adults and children alike; they are thriving social communities (Children Growing up in Indian Slums: Challenges and Opportunities for New Urban Imaginations - Bernard Van Leer Foundation, 2017). This paper explores the correlation between the physical environment and children's wellbeing as well as looks at children's perception towards the physical environment in a slum in Pune city.

LITERATURE REVIEW

The literature review is divided in two subsections. In subsection 2.1 the aspects of wellbeing have been reviewed and in subsection 2.2 five predictors of wellbeing in the physical environment namely crowding, noise, privacy, territoriality, and housing quality were identified for the study.

Wellbeing

Wellbeing as a concept differs based on goals of life across communities around the world. These may also vary across ethnic diversities (Weisner, 2014). Wellbeing includes subjective as well as experiential aspects. According to Weisner (2013), understanding wellbeing in a range of communities that are exposed to differing beliefs as well as values and practices requires qualitative as well as quantitative methods.

A key concept to understand child wellbeing could be individual experiences and their meanings within the community as well as wellbeing and circumstances such as health, resources, uncertainties etc. (Weisner, 2014). The conceptual framework widely referred for child wellbeing in an ecological context is Urie Bronfenbrenner's (1979) work which states that the child is an individual that grows enmeshed in sociocultural relationships in the closest sphere of influence. Here the physical environment also plays an important role as along with interpersonal relationships, the child also begins exploring its immediate environment.

Predictors of Wellbeing in the Physical Environment

"Once people are compelled to reside in slums as they cannot afford elsewhere, they still possess the capability to value and optimise on their housing attibutes." (Kirk, 2017)

Crowding, noise, privacy and territoriality, and housing quality are attributes of the physical environment that predict wellbeing.

Crowding

The standard metric used to determine crowding is 'persons per room'. Globally, experience of crowding and its tolerance differ across countries and cultural contexts (Liddell & Kruger, 1987). Children in the global south, especially South Asian countries are familiar with crowded situations as compared to their Northern counterparts. The US census considers more than 1 person per room as crowding, however; densities in Indian families is observed to be in the range of 0.67 to 5 persons per room (Evans et al., 1998). Crowding in the residence has been known to affect parent-child communication (Evans & Wachs, 2010). Crowded households were also responsible for adverse socio-emotional functioning of the children as well as their parents (Ani & Grantham-McGregor, 1998), with reduced parent-toddler interaction (Wachs et al., 1993). On the other hand, crowding has been known to affect social relationships among family members, forcing to withdraw themselves to cope with feelings of crowding (Evans et al., 2001). Children in crowded households in European countries have been known to be affected by learned helplessness (Evans & Stecker, 2004).

Noise

Exposure to noise may be unpredictable as well as uncontrollable at times. Chronic exposure to noise has been observed to elevate cortisol (a stress hormone) due to increase in stress (Paunović et al., 2011). Multiple studies have reported issues related to learned helplessness due to uncontrolled noise exposure (Hiroto, 1974, Krantz et al., 1974; Evans & Stecker, 2004). Studies have also shown that continuous noise exposure has been known to influence reading acquisition among children (Evans, 2006). However, no evidence from European studies suggests association between psychological wellbeing and noise levels (Ferguson et al., 2013).

Privacy and Territoriality

Territoriality is a mechanism exercised to achieve privacy. Children, like adults have been known to control access to self to create a 'sense of self' (Laufer & Wolfe, 1977), to safeguard privacy. In many situations, especially in India, children have been observed to have limited access to privacy as well as little choice to experience solitude. Children are often subjected to perpetual intrusion as they are seen as dependents (Laufer & Wolfe, 1977), this leads to issues related to 'self-identity' as they are unable to control other's access to self, due to an absence of a primary territory (Altman, 1975). However, another study suggests that children who do not perceive a primary territory, or a 'special place' may be more self-assured in group settings (Zeegers, Readdick, & Hanson- Gandy, 1994).

Housing Quality and Outdoor Spaces

Many children in the global South reside in substandard housing (Govender et al., 2011; Bradley & Putnick, 2012), afflicted by leakages in the structure (Chaudhuri, 2004). Unsafe and inferior quality housing lead to stress among low-income parents (Evans & English, 2002). Further, issues related to self-esteem have been reported by studies related to children living in slums (Chawla, 2016). Noisy and crowded households have been reported to increase overnight stress hormones among primary school participants living in slums (Evans & Marcynyszyn, 2004).

Outdoor spaces in poor neighbourhoods are a problem due to resources of lower quality as compared to the advantaged neighbourhoods (Evans, 2004). These issues are prominent in children of middle childhood (6-12 years of age) (Chawla, 1992); as well adolescents who explore the neighbourhood extensively. Most recent studies have informed children's affinity to formal and sport settings as well as spaces around the home (Korpela et al., 2002; Min & Lee, 2006; Tandy, 1999). Children also prefer places that allows them to be around friends (Korpela et al., 2002; Min& Lee, 2006).

Given the relationship between the children living in urban slums, how they perceive the characters of those places and neighbourhoods where children appreciate available spaces within the poor neighbourhood has been understudied (Castonguay and Jutras, 2009).

Figure. 1: Satellite image of Gulab Nagar slum of Dapodi area with inputs from author. (Image Source: https://www.google.com/maps)

METHOD

Research Aim

The aim of the research is to understand whether the lack of infrastructure in the urban slum of Dapodi, Pune has any correlation with the wellbeing of the resident children.

Study Area

The city of Pune houses 40 percent of the people inhabiting 477 urban slums, wherein the slum population has grown from a modest 8 percent in 1951 to a mammoth 40 percent in 2011 (Mundhe, 2019). As per the Rapid Infrastructure Mapping conducted in the slums of Dapodi in the Gulab Nagar area of PCMC by the non-profit organization Shelter Associates; of the total 1528 tenements, 67% huts are semi pucca, 20% huts are pucca and 13% huts are kutcha. About 85% residents have access to individual water connection for 3 hours daily; and a ratio of 1:64 toilet seat to person ratio is observed with a general cleanliness reported 'poor' in the 6 community toilet blocks. Most of the internal roads are finished in concrete with paving for some roads. The open gutter coverage in the area is around 60% and drainage coverage is around 72% (www.shelter-associates.org). Each tenement is of the average area of 10 sq.m each.

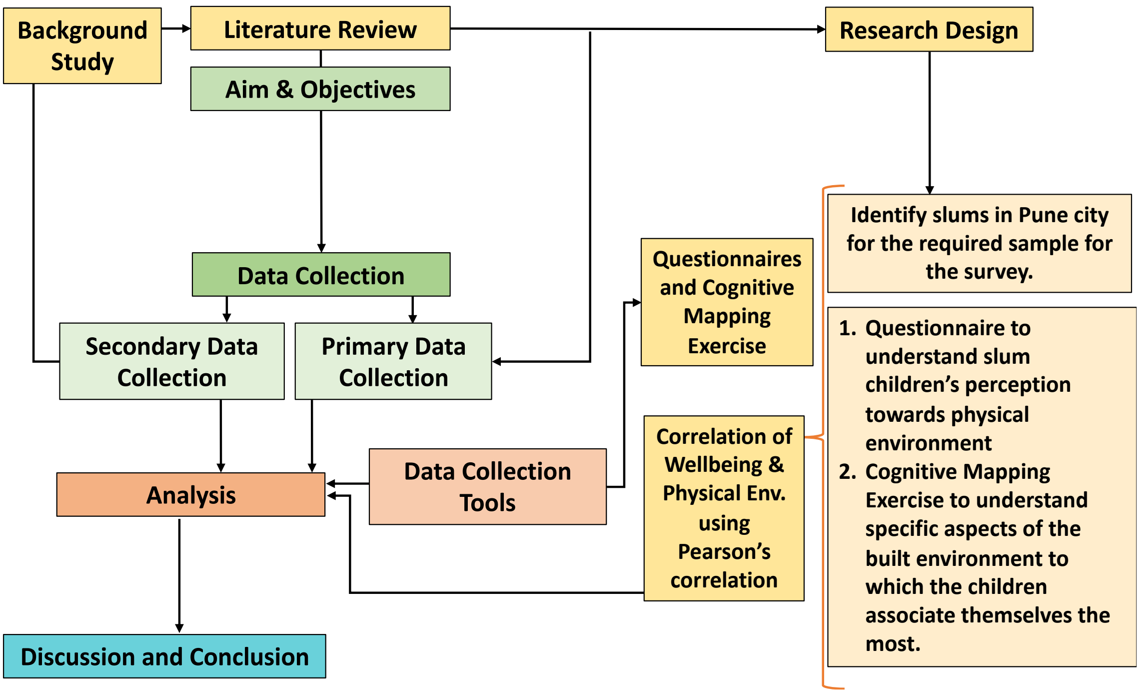

Figure. 2 Research Approach (Source: Authors)

Materials and Methods

This study employed a concurrent embedded mixed method research (see Figure 2). The study intended to measure the relationship between the physical environment (independent variable) and wellbeing (dependent variable) through a correlational analysis. The participants of the study were 32 children living in the slums within the age group of 13 to 18 years. This age group was selected as territorial behavior is more prominent among teenagers, wherein young children are frequent users of public places as they cannot control private spaces (Childress, 2004).

The sample size was determined based on the Central Limit Theorem, wherein no less than 30 samples are to be considered for a study. The initial sample of 48 teenagers, was coded and incomplete responses were filtered out bringing down the sample size to n= 32. As part of the ethical consideration, the parents/guardians were approached for permission. The nature of the study was explained to them and only after permission was granted, the children were approached for the survey. The children were verbally asked for permission to be a part of the survey and those who denied were excluded from the study.

Quantitative Data Collection

The quantitative data collection was conducted using two scales; firstly, the standardized 12 item Stirling Children's Wellbeing Scale (SCWBS) by Liddle and Carter (2015) to measure the emotional and psychological wellbeing of children and secondly, a five-point Likert based questionnaire was administered to measure the attributes of wellbeing crowding, noise, privacy, territoriality, and housing quality.

Qualitative Data Collection

The qualitative data was collected in the form of cognitive mapping exercise where a blank A4 sheet was given, and children were asked to sketch their favourite or preferred spot in their home or the immediate

neighbourhood. A focused group discussion with 8 children ensued wherein they explained the contents and meaning of their sketches. the family, etc. It is to be noted that no symptoms related to the disease are captured here. Table 3 enlists some training data sets for ten patients. Besides these 18 different features, the decision regarding diagnosis in the form of 'Yes' and 'No' is also collected and provided to the system for each training data set. Such 300 patients' data from diversified locations through online questionnaires are retrieved, validated, and delivered to the system.

Quantitative data collection

As mentioned in section 3.2.1 the data elicited from the SCWBS is given below in table 1.

In the subcomponent of positive emotional state of the SCWBS, items ranging from 'I've been feeling calm' to 'I've been getting along well with people', around 67 percent of the children reported a score of 16.09 which is above the average score of 12. For the positive outlook subcomponent which have items ranging from

'I think good things will happen in my life' to 'I think lots of people care for me' 72 percent reported a score of 17.21 for an average score of 12. For the social desirability component 31 percent children reported a score of 7.34. This means that most of the children have a positive emotional state and a positive outlook which include positive feelings, joy and gratitude. As expected, in the social desirability subcomponent, the low percentage of children reporting a higher that average score indicates that the scale has been attempted with honesty especially for the item "I have always told the truth", wherein most of the children have opted for 'some of the time' as their response. As per the authors of the scale any high or an extremely low score in this subcomponent would have to be treated with caution.

As mentioned in section 3.2.2 the data elicited from the five-point Likert based questionnaire regarding the physical environment is given below in Table 2.

Table 1: Stirling Children's Wellbeing Scale (n=32 13-18 yrs. age group)

Sr. No.	Components of SCWBS	Score (n=32)
1	Positive Emotional State (Wellbeing Sub component, 6 items)*	16.09
2	Positive Outlook (Wellbeing Sub component, 6 items)*	17.21
3	Social Desirability (3 items)*	7.34
* Maximum Score = 24 | Average Score = 12 | Minimum Score = 0 for Sr. No. 1&2 Maximum Score = 12 | Average Score = 6 | Minimum Score = 0 for Sr. No. 3		

Table 2: Physical Environment Domains (n=32 13-18 yrs. age group)

Sr. No.	Attributes of the Physical Environment	Score (n=32)
1	Feeling of Crowding and Noise (7 items)*	14.87
2	Need for Privacy, (2 items reverse coded)*	1.93
3	Exercising Territoriality (7 items)*	18.46
4	Housing Quality and Outdoor Spaces (10 items)*	21.03
* Maximum Score = 28 | Average = 14 | Minimum Score = 0 for Sr. No. 1&3 Maximum Score = 8 | Average Score = 4 | Minimum Score = 0 for Sr. No.2 Maximum Score = 40 | Average Score = 20 | Minimum Score = 0 for Sr. No. 4		

Around 53 percent children acknowledged the feeling of occasional crowding and noise but did not report negatively against it, the remaining children were comfortable sharing the same space with their siblings and other family members. Only 7 percent children in this case expressed the need for privacy and felt that the lack of space led them to spending more time outdoors. 66 percent of the children reported to have reported **not** to have liked playing alone or being alone. Most of the children responded 'never', when asked if they called any place within their home as 'their own', implying that they did not miss having their own space. When it came to housing quality, 75 percent children felt that the homes were adequately lit and ventilated. Even in the case of children who reported satisfactory indoor comfort, it was observed that they spent most of their time outdoors with peers and returned to their dwellings only in the evening hours. When asked about outdoor spaces around 25 percent children reported preferring indoor games to outdoor sports.

Correlation between Wellbeing and Crowding & Noise: While investigating the correlation between children's wellbeing with crowding and noise, the correlation coefficient of 0.348 indicates positive correlation. This is supported by the p-value of 0.0509 is observed with a reasonable level of confidence.

Correlation between Wellbeing and Privacy: The correlation coefficient of -0.0915 indicates a weak negative correlation between wellbeing and privacy. This association cannot be considered statistically significant due to p-value of 0.618 at $p< 0.05$.

Correlation between Wellbeing and Territoriality: The correlation of -0.0684 indicates a very weak negative correlation, wherein as territorial behavior increases, wellbeing decreases. However, this association cannot be statistically concluded as significant.

Correlation between Wellbeing and Housing Quality and Outdoor spaces: The coefficient of 0.0881 is a weak positive relationship, however, a meaningful connection cannot be established due to a non-significant p-value.

Qualitative Data Collection

The qualitative data was collected in the form of a cognitive mapping exercise wherein, as a part of the focused group discussion the children were asked to sketch the place which they preferred the most. Most of the children said that they preferred spending time at the open spaces near the slum which was located near the railway line. An example of the cognitive exercise is that of a 15-year-old child that has drawn a sketch in figure 3 of the space outside his house, where he and his group of friends sit and chat on the cot. Due to the restrictions of space within the house, this cot is also where he sleeps during the night and feels a sense of ownership towards the object at times. However, he also mentioned that when his father occupies the cot, he and his friends often turn to open spaces adjacent to their homes.

Figure. 3 Sketch of a cot outside the house by a 15 year old boy.

Table 3: Pearson's Correlation between Wellbeing and Physical Environment (n=32 13-18 yrs. age group)

	Wellbeing and Crowding & Noise	Wellbeing and Privacy	Wellbeing and Territoriality	Wellbeing and Housing Quality & Outdoor Spaces
Coefficient (r)	0.348	-0.0915	-0.0684	0.0881
N	32	32	32	32
T statistic	2.033	-0.503	-0.375	0.484
DF	30	30	30	30
p-value	0.0509	0.618	0.709	0.631

CONCLUSION

Wellbeing and its correlation coefficient of 0.348 with crowding and noise demonstrates that in the case of the slum physical environment, coping towards noisy and crowded environments along with a certain degree of flexibility among the residents is observed. In this context, crowding need not necessarily be a negative aspect. Extraneous variables such as shared resources and mutual assistance among slum dwellers may be contributing positively to wellbeing, helping to mitigate the negative effects associated with a densely populated noisy area. With regards to privacy and wellbeing, a weak negative correlation suggests that the children do not like being alone or playing alone. An inverse relationship is observed in this case, wherein children have reported preference of group settings as well as being comfortable amidst other people sharing the same space. A correlation coefficient -0.0684 for territoriality does not yield any statistical evidence. Here, adaptability, resilience, sense of community and social interactions may be more dominant. For wellbeing and housing quality, weak positive but statistically insignificant correlation is observed, implying that there may be other variables such as the challenges faced by the occupants as well as the children due to limited financial resources as well as dealing with poverty situations could be more significant to their wellbeing. It may however be prudent to note that a larger sample size may yield different results. On the other hand, variables not considered in this study may have a more profound effect on the wellbeing of children.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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A Journey through Sacred Spaces - Exploring Multi-Sensory Space for Mental Wellness

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Abstract— From prehistoric time, sacred spaces play an important role in day-to-day life and are considered integral part of human wellbeing. These spaces also had social and cultural significance. It is believed that people use these spaces to communicate with God and at the same time experience a sense of calm, relief and peace of mind. Throughout the ages, people across various faiths and traditions have sought comfort and spiritual rejuvenation within the confines of sacred spaces, through the practice of prayer or meditation. This research studies the different sacred spaces of people of different faiths over different ages and how contemporary religions use these sensory elements to stimulate the senses in worship places. It evaluates the scale and proportion, orientation, layout, open spaces, approach methods, and landscape of these spaces, as well as their profound connection with the human senses. This study evaluates how sensory elements such as acoustics, lighting, colours, odour, and ambient temperature are conducive in creating the divinity of the space, be it for prayer or meditation. This study endeavours to understand the intricate relationship between architectural design, spiritual experiences, and human well-being within sacred spaces with distinct consideration for prayer rooms and meditation space. Built environment plays an enormous role in regulating our moods and stimulating our senses to engage in meaningful self-reflection, which manifests meditation, is often scarce and could be improved by including relevant elements.

Keywords: Wellbeing; Sacred space; Mental health; Religious space; Built Environment.

INTRODUCTION

"We shape our buildings, and afterwards, our buildings shape us." (Winston Churchill). The built environment has the power to affect our well-being, productivity, social interactions, and overall quality of life. The buildings we create not only serve functional purposes but also play a role in shaping our behaviours, attitudes, and overall well-being. Today, people spend most of their time in a built environment, be it for work, leisure or rest. Hence, built environment plays an enormous role in regulating our moods and stimulating our senses.

From prehistoric time, sacred spaces play an important role in day-to-day life and are considered integral part of human wellbeing. It is believed that people use these spaces to communicate with God and at the same time experience a sense of calm, relief and peace of mind. A sacred space is a space that is built to help people escape from their ordinary everyday life to an extraordinary place.

AIM

Identifying elements of architectural design in creating a space to promote self-organization and positively impact human wellbeing

OBJECTIVES

- To identify the similarities in terms of architecture and quality of spaces of sacred spaces across

- different religions and cultures.
- To explore the architectural elements, symbolism, character and spatial organization of sacred spaces which are commonly used in major religions in the world
- To compare contemporary sacred space
- To find principles for creating sacred space for wellbeing.

LITERATURE REVIEW

Studies about people's opinions about sacred space have shown that almost 80% believe that religion is part of their life. A survey of people's perceptions of what makes a place scared showed that the interior and exterior environment (48.6%) are the most important features that make a space sacred. Other important factors include the natural environment (31.5%), lighting (28.8%) and sound from natural elements is (23.6%) (Garg 2010).

There is research on the effect of spending time with the natural environment. Compared to the static indoor spaces, people respond better to multisensory spaces outdoors. (Naomi,2021). This research is a journey through sacred space which may or may not have a religious belief.

METHOD

Sacred spaces are among the world's most impressive and permanent monolithic buildings in existence. When we look at religious buildings, every religion and culture form their own way to connect with God. Despite the differences in the form and architecture of the sacred spaces of the different religions, this research identifies the commonalities in the character of their experiential spaces. Multisensory variations can have an effect on people (Altomonte, 2020). This research is to try to identify these elements and variations in contemporary sacred buildings to determine strategies for wellbeing.

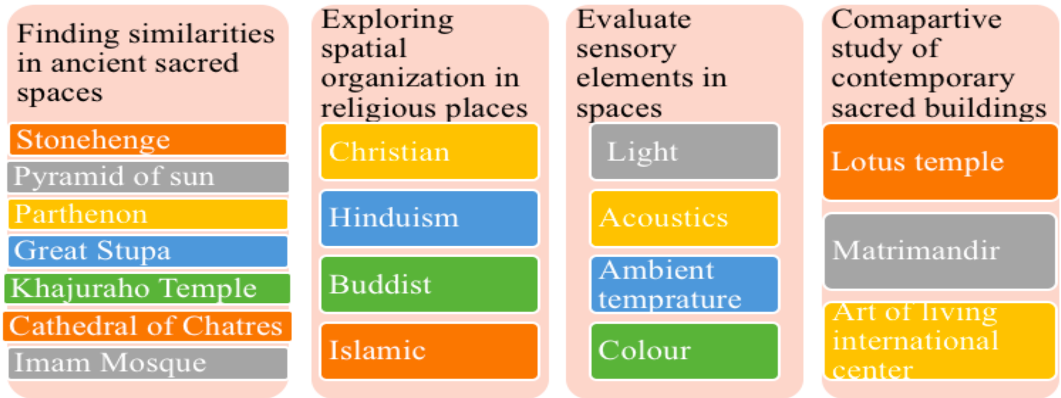

Figure. 1: Methodology

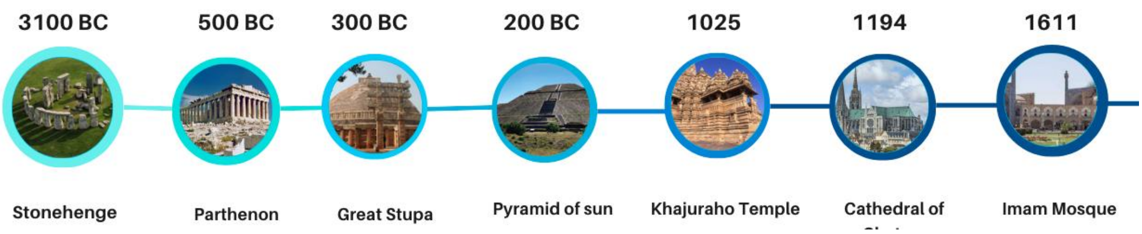

Figure. 2: Timeline of ancient sacred spaces

Ancient sacred space

There are commonalities and differences between architectural sacred spaces made in a variety of time periods and places.

Stonehenge

Stonehenge, a prehistoric monument with orientation toward sunrise on the summer solstice. It is built on elevated land and people assemble there during winter. It consists of an outer ring of sarsen standing stones, each approximately 13' high and 7' wide weighing 25 tons connected with horizontal lintel stones. (pearson, 2023)

Parthenon

The parthenon, located on the acropolis in athens, greece, is a temple dedicated to the goddess athena. The temple's harmonic proportions, precise construction, and lifelike sculptures have been celebrated. The sacred nature of the parthenon is further emphasized by its location on the acropolis, a prominent elevated area in athens dedicated to various deities. Pilgrims and worshippers would ascend the acropolis to reach the temple, engaging in religious ceremonies and festivals. The parthenon worship, has gone through various phases of use and modifications over the centuries, during which it became church, mosque and even military barrack.

Great stupa

The great stupa is a symbol of ancient buddhist architecture and was built around 3rd century bc. Located on the sanchi hill, the stupa is a dome structure built over the relics of buddha. The entrances are adorned by four gates in cardinal directions. The monument adorns sculptures of royalties with no statue of buddha. The stupa encompasses four passages or thoranas representing love, trust, fearlessness and peace. It also has burial ground around.

Pyramid of sun

The pyramid of sun was built on a carefully selected location where it was possible to see the sun rise and sun set on specific dates, possibly for agricultural reasons. This structure is considered as a sacred space due to its layout, alignment with celestial events and presence of various temples and structures with potential religious significance. The pyramid was built with red volcanic rock with upwards stair steps leading to the top of the structure where the temple was built. The alter at the top has not survived.

Khajuraho temple

Khajuraho temple also known as kandariya mahadeva temple is a hindu temple from 11th century ad located at khajuraho in the vindhya mountain range of central india, madhya pradesh. The temple is built with hard river sandstone and granite and ordained with rich sculptures, both inside and outside. The entrance of most of the khajuraho temples faces east, i.e., in the direction of sunrise. Like almost all hindu temple designs, khajuraho temples follow a grid geometrical design called vastu-purusha-mandala.

Chartres cathedral

Chartres cathedral, is a christian church dedicated to the virgin mary. The building follows gothic french architecture and is noted not only for its architectural innovations but also for its numerous sculptures, particularly figure sculpture and its much-celebrated stained glass fixtures. It is built of limestone and stands 112 feet high and 427 feet long with large clerestory—the massive weight of which is required to use flying buttresses. In the cathedral treasury, immense amount of sculpture, particularly figure sculpture, ranging from large column statues to miniatures.

Imam mosque

The imam mosque consists of two structures, a gorgeous entrance and main mosque with a courtyard between. The mosque has blue tiles with a large dome over it. Mosque faces the southeast (facing mecca), and it acts as a communal prayer room, community gathering and religious education. The mosque has a unique acoustic feature whereby, any noise produced is transmitted to all parts of the dome and can be heard at the same pitch in all places within the structure.

Table 1: Comparison of ancient sacred spaces

Name, Location & Year	Orientation	Function	Scale & Proportion	Material	Important features
Stonehenge, England (3000-2000 BC)	North East	Scared site designed with agricultural concerns (planting season) Worship ancient earth deities	300ft in diameter. 22ft tall Circular geometry	Bluestone (igneous stone)	Enormous upright megaliths. Interlocking grooves and notches. Summer solstice sun angle.
Parthenon, Greece (447-438 BC)	East	Temple of goddess Athena. On hilltop for watch and protect from attack	228 ft long 101 ft wide 62 ft tall Rectangular geometry	Marble	Harmonic proportions, precise construction, and lifelike sculptures
Great stupa, Sanchi (3rd BC)	All 4 Cardinal direction	Stupa depicted sign and symbol of buddha presence. No image to be worshipped, but instead for followers to meditate on his teaching	120 ft diameter 54 ft tall Circular geometry	Brick	3d recreation of the universe, and the center spike symbolize the axis through earths center around the universe revolves
Pyramid of sun, Mexico (150-225AD)	Main axis in North-South direction	Temple (believed to be linked to God, the underworld, creation and afterlife	700 ft long, 210 ft tall, Pyramidic geometry	Hewed tezontle, red coarse volcanic rock of the region	Ornamentally decorated walls
Khajuraho Temple, Madhya Pardesh (1000 AD)	East	Temple dedicated to Shiva.Intricate cosmic mountain reaching towards the sky.	102ft long 66 ft wide 102 ft height	Sandstone, Granite foundation	Emphasis on the harmony created by the unification of opposite elements (birth/death, fire/water etc.)
Charters chathedral, France (1194-1250AD)	West (Alter at East -People Face East)	Workship of St. Mary	427ft long 112 ft tall Plan resembling cross	Limestone	Rose windows Unprecedented height. Flying buttress. Light entry from the rose window falls on the statue of Virgin Mary
Imam mosque, Iran (1611 AD)	South East facing Mecca	To support and guide prayer toward Mecca	52 m tall	Brick and tiles	Tall towers Abstract flora designs.

Exploring architectural elements and spatial organization in religious places

Prayer and meditation are closely linked to all religions, it is interesting to understand some of the fundamental differences between the two.

- Prayer is based on belief system while meditation does not require any belief system
- Prayer is essentially communication with God while meditation is communication with self.
- Prayer is a religious activity and under specific doctrines while meditation is not related to any religion or community

Prayer essentially involves communication to God. This engagement results in reduction in stress, peace of mind, better mental wellbeing and better social engagement. Meditation could also yield similar results by providing the right ambience and guidelines, and since it is devoid of any religion, could be more harmonious and even yield better results.

Space and architectural elements vary with the religions. For comparing, four religions - Buddhism, Christianity, Hinduism and Islam spaces are considered below.

Buddhism

The primary form of worship in Buddhist temples involves meditation and chanting together or individually. Structures can vary from standalone building to a complex. Generally these structures are located in good natural surroundings and if not, the surrounding ambiance is created by constructing water bodies and other natural elements such as gardens. Most Buddhist temples consist of a main hall and a meditation room with passages. The passages are symbolic of a journey to enlightenment; they can be straight, indirect or circumbulatry. The hall is always elaborately decorated with a statue of Buddha while the meditation room is kept bare, simple and quiet.

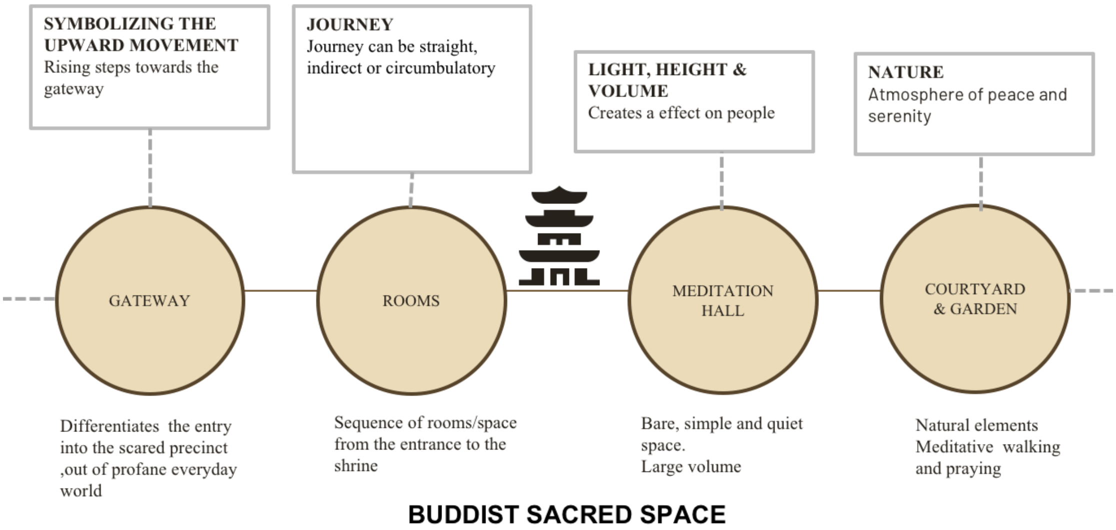

Figure. 3: Architectural elements of the Bhuddist space

Hinduism

The Hindu temples are generally east facing, captivating rising sun's energy and the main axis is in the east-west direction. The plan of the temple consists of a symmetrical geometric design with a grid of 64 or 81 squares laid out in Vastu-Purusha-Mandala, an ancient form of building science in Hindu Vedas. The main deity of the temple is placed in the centre which is usually a sculpture in stone. The outer squares house shrines of the other gods. The orientations of the inner elements are based on astrology and astronomy. The journey from the gateway of the temple to the main shrine takes a visitor through a series of spaces with increasing volumes and culminates at the shrine of the main deity.

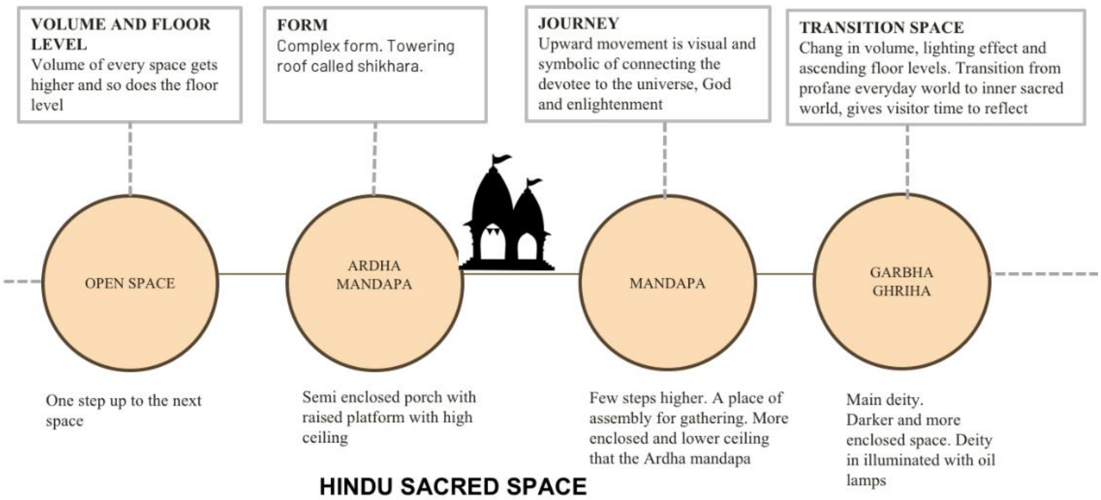

Figure. 4: Architectural elements of the Hindu space

Christianity

Christian churches generally face east with the entrance for the public from the west. The worshippers face east while worshipping with the priest/s leading the congregation. The church structure broadly consists of a lobby, a worship place and a sanctuary with the alter. The lobby is generally with low ceiling and functions as a transition space to move into worshipping or meditation. The worship place is the largest space and the worshippers can sit or stand and pray. The sanctuary is for the priests leading the congregation and is generally an elevated platform with the alter placed within in complete view of the worship space. The sanctuary is well decorated with flowers, candles and cross which constitute the central figure. Worshipping mainly consists of hymns and set prayers which are sung together.

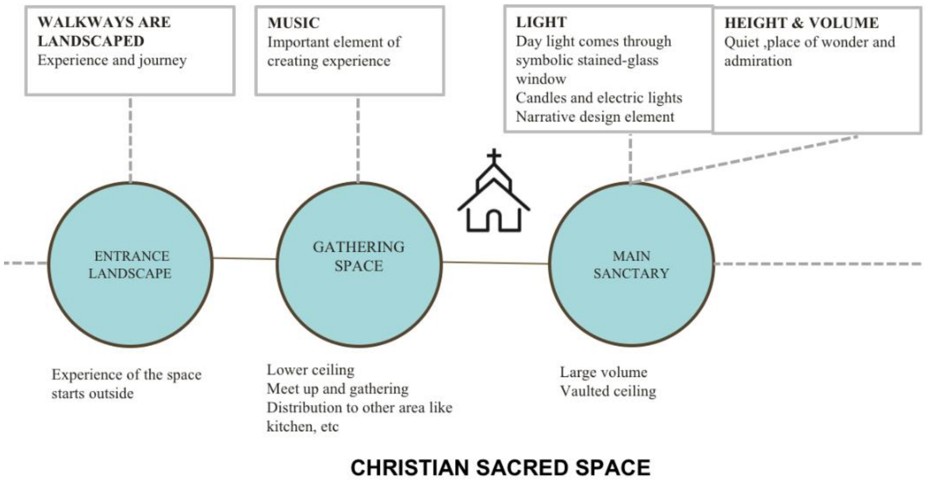

Figure. 5: Architectural elements of Christian space

Islam

As per Islamic belief, Mosques are designed to face Mecca. Mosques are generally rectangular in shape with dome roof. As per the Islamic religion, prayers are required to be offered at specific times over the day and since the congregation can be large, the worship space in the Mosque can be covered or open to sky or combination depending upon the number of people and the climatic conditions of the place. Furthermore, the rectangular worship spaces are free of columns and other obstructions. Mosques are devoid of any sculptures but rich in art with geometrical shapes, precious stones and lighting. Water bodies are also consistent features of mosques.

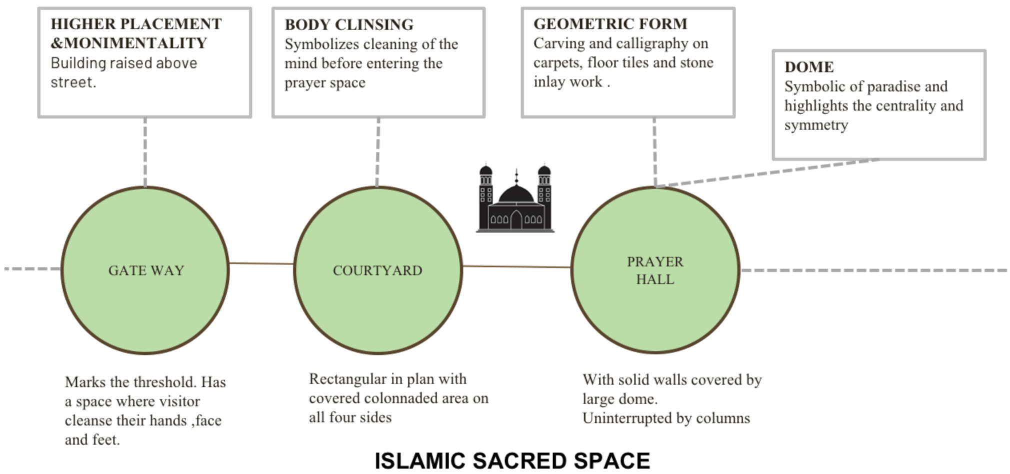

Figure. 6: Architectural elements of Islamic space

Multi-sensory space in sacred space

Luminous

Eyes are the for vision and an input for circadian rhythms. Light is a powerful element for spirituality. Light and shadow interaction creates meditative space. (meirosev, 2008). Circadian rhythm - there is ample basic science evidence to support an association between circadian rhythms and mental behavior (william, 2020). Circadian cycle enhance mental pleasure and benefit wellbeing (altomonte, 2020). Colour, light, form, texture and pattern are perceived by visual inputs.

Thermal comfort

Thermal comfort can vary from person to person. Thermal satisfaction is achieved when people have choice. Thermal satisfaction support wellbeing. Thermal comfort can be achieved by passive or active systems. Thermal variability either over time or across different parts of the body enhance positivity (altomonte, 2020). Sun is the source of energy and morning sun has good spectrum of light with vibrance.

Acoustics

Acoustics play important role in achieving mental peace. Preventing unwanted noise is necessary but smoothing sound is added for physio psychological wellbeing. Sacred geometry is not just symbolic representation but it allows the dynamic movement of sound energy. (mayank, 2019)

Indoor environmental quality

Pleasant scents increases the tolerance of subjective comfort of feelings and emotions.

Characteristics of contemporary sacred buildings

Case study of contemporary building are done to examine the identified elements of sacred spaces and the variations in multi- sensors.

Table 2. : The evaluation of characteristics of some of the contemporary sacred spaces

Religious / Sacred place	**Lotus Temple, Delhi**	**Matri Mandir, Auroville**	**Art of living Internal Center, Bangalore**	**Findings**
Orientation of entrance	East	East	East	All sacred buildings are oriented to get morning sun
Planned journey to the sacred space	Yes, East-West	Yes, East-West, Circular path going upwards leads to sacred chamber	Yes,East- West	Planned journey to reach the sacred space which is through scenic natural environment.
Integration of natural elements along the journey	Yes ,Water	Yes, Water	Yes, Water along the pathway	Dynamic nature of flowing water act as stimuli
Elevated scared chamber	Yes	Yes	Yes	Allows to relive oneself from day to day activities
Monumental sacred space with special lighting effects	Yes	Yes	No	Play of light and shadow create meditative space.
Focal point	Yes	Yes	No	Helps in concentration
Colour & ornamentation inside	No	No	Yes	Colourful interior distracts.
Iconic structure	Yes	Yes	Yes	Different from the day to day activities spaces
Thermal Comfort	Passive conditioning	Active conditioned	Natural ventilation in moderate climate	Thermal comfort is important for satisfaction
Function	Praying	Meditation	Praying	Praying can happen in group, to meditate one needs to be them self

CONCLUSION

The built environment should have a positive impact on occupants. The absence of illbeing is not enough for wellbeing. The introduction of intentional environmental stimulation can have positive outcomes. Following are the quality of space matrix recommended for people to spend time for contemplating prayer or meditation for wellbeing.

- Elements of nature - landscapes and water bodies should be an integral part of the built environment. The dynamic nature of natural elements stimulates visual senses , which help people to escape from the environmental boredom of static built environment. Adding plants and trees with high visual stimuli, varying texture & colours and scents can enhance satisfaction. Trees gives vertical dimension.
- The orientation of the building to obtain morning light with the morning spectrum and the temporality enhance the circadian cycle.
- Monumental scale – larger than the surrounding buildings. People should have different dedicated spaces for meditation or multi faith space where they will experience a distinctive space. The journey toward this will be a planned journey that allows for a transition. This transition allows us time to focus on ourselves.
- A focal point that helps to focus and concentrate. It can be an object or a spectrum of light.
- Light - Diffused and soft light is preferred for calmness. Light can be used to highlight or focus. Contrast of light and dark can create variability. Colour of interior is kept bare, simple and quiet.
- Thermal comfort – higher level of personal control is required for thermal satisfaction. If it is active conditioned, should be for a short period.
- Acoustics- the space should be away from outside noises. The long pathway to inner space helps to keep the silence. Few sounds enhance positivity in people like sound of moving water and chirping bird.
- Indoor environmental quality- add scents which leads to higher satisfaction.

The built environment should be dynamic with sensory variabilities. These stimulate enhance the positivity, increase productivity and improve psychological resilience.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Urban Wellness: Assessing the Dynamics of Street Networking and Green Cover on Urban Wellbeing

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Abstract— Cities are undergoing a thorough transformation due to rapid urbanization and the increase in population, resulting in increased built-up densities. There is a significant emphasis on the built environment, with green spaces receiving the least attention in preservation. There are difficulties in preserving people's overall physical and mental wellness and the relationships between the built environment and open spaces inside the urban fabric. It had been realized to be crucial during the recent COVID-19 pandemic. The study examines the relationship between the urban built environment and the well-being of urban societies, mainly focusing on the share of open spaces such as community parks and their overall integration with the built surroundings. The connectedness was assessed using Space Syntax analysis in DepthMapX. The study is carried out for a few distinct wards of Kolkata to determine the overall correlation between the spatial pattern and the distribution patterns of COVID-19 infection within the sample wards of the city. Open space proportions, road connectivity, angular connectivity, segment length, and their integration into the nearby residential areas are considered. The study aims to discern which factors influence the spatial distribution of COVID-19 and which are inconsequential. The findings of this correlational research offer evidence that street networking dynamics in association with the availability of open spaces directly impact people's well-being. The conclusion of this study provides insights into the relationship between the built environment and urban well-being, which is vital in developing a healthy society.

Keywords: Built Environment; Space Syntax; Well-being; Depth Analysis; Integration; Connectivity

INTRODUCTION

Urban wellness is a broad term that includes people's social, emotional, and physical health while they live in urban areas. Creating a healthy urban lifestyle is becoming increasingly important, yet being overshadowed by the built environment as cities experience fast change and encounter obstacles like growing populations resulting in high-density settlements. It is time for policymakers to prioritize urban well-being, specifically if the cities are to be built to be more resilient and sustainable. The study explores the multifaceted connection between the built environment of cities and urban health to evaluate the critical role that urban wellness plays in our cities' general health and vitality.

The city's built environment comprises buildings, open spaces, and street layouts. Urban street networks' accessibility, integration with the neighbourhood, and connectedness, as assessed in this study using Space Syntax analysis, are found to be intangible factors affecting city residents' mental and physical health. Understanding this complex link is crucial for urban wellness. The study indicates that efficient planning of roads can improve public health resilience and is essential in determining the dynamics of metropolitan areas. Therefore, understanding the importance of street networks is crucial for urban planners who want to build communities that value and promote the general well-being of their residents.

Nevertheless, a street network-friendly design is crucial for walkability, improving local physical activities and healthy communities (Mohammad, 2021). To achieve this, planners should consider variables such as link, accessibility, least-angle, and centrality in their street connectivity designs (Mohamad, 2014).

It has been constantly observed that there is a significant connection between urban well-being and the morphometric features of their built environment. This long instinctive understanding has reflected an essential interconnectedness between these two that needs to be further seen. As the COVID-19 pandemic grew, this became particularly obvious in the spatial distribution of cases worldwide and is the prime motivation behind this study. Therefore, the study aims to investigate the influence of street networks and open spaces on the threats to urban wellbeing, such as the distribution patterns of any pandemic, such as COVID-19.

The COVID-19 pandemic had a wide range of impacts on communities worldwide, with case severity differences related to population density, sanitation standards, and economic situations. When considering these elements holistically, it becomes clear that they are intertwined with each area's current urban form. Understanding how these characteristics are interrelated within the urban fabric is a primary goal of our study. Six neighborhood wards in Kolkata, West Bengal, India, have been chosen as the study's boundaries to go deeper into this connection. The study aims to interpret the complex relationships between the urban structure—embodied in features like accessibility networks and open space densities in a rapidly growing urban world, where the spatial demand is also shooting upward. Integration, Connectivity, angular Connectivity, and segment length are some of the main street network attributes that will be evaluated in DepthMapX. Where The term connectivity is applied to explain the number of connections each street has to its direct neighboring streets; integration measures how many turns one has to make from a street segment to reach all other street segments in the network using the shortest paths; segment length refers to the size of the individual line segments that make up the street network or space being analyzed; and angular connectivity refers to the number of connections or links that a segment (e.g., a street or pathway) has with other segments, considering the angle between them.

The paper demonstrates the study through different sections, including a literature review followed by the study's methodology, analysis and results, and finally, discussion and conclusion.

LITERATURE REVIEW

Urbanization has a complex impact on well-being, with both positive and negative effects. However, it also brings challenges such as overcrowding, pollution, and social deprivation, which can lead to stress-related illnesses (Godfrey, 2005). The shift from rural to urban living can also have significant ramifications for mental health, particularly for new migrants, and calls for the prioritization of psychosocial support (Halbreich, 2023). Therefore, while urbanization can offer benefits, it also requires careful management to ensure the well-being of urban dwellers.

Newman (1981) suggests that higher density can benefit the populace and planners, but this requires better planning and design. Access to green spaces is associated with greater well-being in urban populations (Goldenberg, 2018), highlighting the importance of maintaining and restoring these areas. Furthermore, Brown (2015) investigates the relationship between urban form and well-being, discovering a trade-off between dwelling space and proximity to the city centre and a negative correlation between life satisfaction and total city compactness.

Research consistently shows that green spaces, including open spaces, positively impact health. They improve mental and physical health, reduce stress, and enhance social interactions. However, socioeconomic factors can influence the extent of these benefits (Kabisch, 2017). Despite this, revitalizing green open spaces can still significantly impact community health and environmental sustainability (Dewi, 2018).

The built environment and its impact on connectivity have been explored in various studies. Moreover, (Savić, 2017) and (Krasheninnikov, 2019) both emphasise the role of the built environment in promoting connectivity, with Savić focusing on wireless communication infrastructure and Krasheninnikov on the spatial structure of macro-space. (Leyden, 2011) extends this discussion to the public sphere, highlighting the importance of the built environment in fostering connections between residents and their cities. When viewed as a whole, these studies emphasise how important the built environment is for relationships in terms of social interactions and physical infrastructure. The built environment fosters community and well-being (Thompson, 2014). The well-being of residents in care facilities can be improved by design features such as spatial legibility and interconnection (McIntyre, 2017). For older adults in low-income communities, street connectivity and social cohesion are associated with capability well-being (Engel, 2016). However, the impact of the residential built environment on social well-being requires further exploration (Janahi, 2018).

The social logic of space is a complex and multifaceted concept, as explored by (Hillier, 1984) and (Kus,1983). Hillier's work delves into the analysis of settlement layouts and the spatial logic of arrangements. At the same time, Kus emphasizes the role of space in the self-definition of society and the relationship between social and cosmological order. (Peter,2009) further expands on this, discussing the reassertion of space in social theory and the need to denaturalize space and spacetime. (Gans,2002) highlights the underlying connections between space and society, primarily how collectivities use and modify natural space, to further this discussion. Together, these studies highlight how crucial it is to comprehend how society constructs and represents space and the dynamic interactions between society and space, i.e., the social logic of spaces or the spatial syntax.

Space syntax analysis, a method developed by Hillier and his colleagues, has been used to model and analyze urban spaces, focusing on their social, economic, and cognitive aspects (Nes, 2018). This approach, which emphasizes the relationship between spatial configuration and human behaviour, has been instrumental in urban design, including urban plazas (Bendjedidi, 2019). Research on the spatial distribution of COVID-19 has revealed significant clusters in various regions. In Nigeria, Lagos State was identified as a hotspot, with higher GDP per capita and lower literacy rates associated with higher case numbers (Daniel, 2021). It was discovered that the virus had unequal social and spatial distributions in New York City, USA and that these distributions were correlated with social vulnerability markers. (McPhearson, 2021). In China, the virus was found to be spatially dependent, spreading from Hubei Province to neighbouring areas (Huang, 2020). In Brazil, the capital and surrounding areas had the highest case rates, necessitating a particular arrangement of intensive care beds. (Pedrosa, 2020). Highlighting the importance of understanding the spatial distribution of COVID-19 for effective control and prevention measures.

A range of studies have explored the spatial distribution of COVID-19 in urban areas. In Rio de Janeiro, high infection and death rates were found in the Southern and Northern Zones (Cavalcante, 2020). In Mexico City, the distribution of COVID-19 was influenced by water availability and household overcrowding (Rodríguez-Izquierdo, 2020). The metropolitan area of São Paulo State was found to be a hotspot for the virus (Rex, 2020). These studies collectively highlight the complex interplay of environmental, social, and economic factors in shaping the spatial distribution of COVID-19 in urban areas.

Ghazali (2021) discovered that older people and populated regions in Bandung, Indonesia, were linked to increased COVID-19 cases; however, green cover was not particularly mentioned. Rodríguez-Izquierdo (2020) emphasized how socioeconomic and environmental factors shaped the COVID-19 distribution in Mexico City, but it omitted any mention of green cover. (Pallathadka, 2021) investigated the amount of green space and the susceptibility of various racial groups to COVID-19 in four US cities. The findings suggested that the amount of green space may influence COVID-19 vulnerability. More research is required to accurately establish the relationship between green cover and COVID-19 distribution in urban environments.

Studies have shown that green areas favor physical and mental health linked to well-being (Goldenberg, 2018). The built environment, which includes street connections, greatly enhances community and well-being (Thompson, 2014). Research on the spatial dispersion of COVID-19 highlights the importance of comprehending the intricate interactions between environmental, social, and economic elements in metropolitan settings, encompassing the possible impact of vegetation on the virus's spread (Ghazali, 2021; Rodríguez-Izquierdo, 2020).

METHOD

The research methodology can be broadly organized and differentiated into four significant steps: Data collection related to COVID-19 risk factors, analysis of built environment attributes, network analysis in DepthMapX, and calculation of Pearson's correlation.

Data Collection

The data collection comprised two phases: first, identifying wards in Kolkata Municipal Corporation according to their population density, settlement pattern, and networking influenced the COVID-19 intensity of their respective wards. As a result of this, a total of six wards were selected under the Kolkata Municipal Corporation. The population density, risk zone category, and street networks were collected through different secondary sources. The risk zone category was based on the susceptibility index, social awareness, social distancing, and health hygiene indexes (COVID-19 Susceptibility Index: A statistic used to assess the likelihood that individuals or areas would be affected by COVID-19 based on criteria such as health, demographics, and socioeconomic status).

The geospatial processing of data was undertaken using GIS. The ward boundaries were delineated, and street networks were prepared for further analysis. The ward-wise population was noted, and post-processing of the spatial database, built-up share (in per cent), and open space share (in per cent) were calculated in GIS. The street networks of each ward were imported to DepthMapX for connectivity assessment of each ward. The street network connectivity was assessed using four significant parameters: segment length, connectivity, angular connections, and integration. The average network connectivity for each ward was calculated for the given parameters. Finally, Pearson's correlation was calculated for all the considered variables, and based on the correlation values, the inferences were prepared.

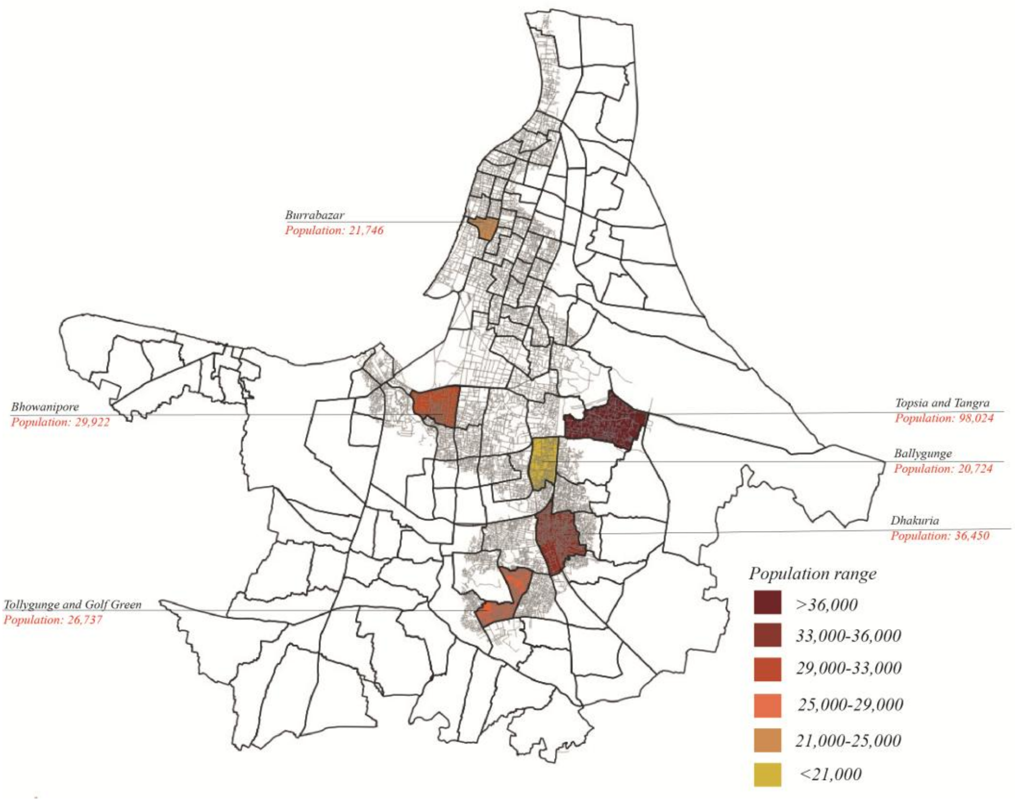

Figure 1: Selected wards and their population with road network representation

Built Environment Analysis

First, the selected ward's OSM data, which included detailed information about the building footprints and road network, was acquired. The entire area covered by the built-up features within the chosen ward boundary was then estimated by importing the geospatial data into the QGIS program. The extent and distribution of the built-up regions within the ward boundary were quantified and visualized using spatial analytic tools. The official population datasets for every ward were acquired concurrently. The entire ward's area, the building footprint (The term "building footprint" refers to the outline or perimeter of a structure's base as seen from above. It is essentially the shape of the building's ground-level area), and the open lands area were calculated in GIS. Following this, the road network is analysed for additional insights.

Network Analysis in DepthMapX

A comprehensive approach was used in networking analysis to analyze the relationship between street network attributes and the spatial distribution of COVID-19 cases within targeted wards. The street network data was imported, ensuring its compatibility with DepthMap X software for subsequent analysis. Afterwards, the street data was transformed into a segment map in DepthMapX, allowing for an in-depth analysis of integration, connectivity, angular connectivity, and segment length. The average values of the attributes derived from the street network data were obtained using segment analysis, offering insights into the segment's length, connection, and crucial integration with the surrounding urban fabric. The average attribute values across the wards helped to derive representative metrics that showed the general effectiveness of the street network and its possible influence on the spread of COVID-19. In addition to network analysis data and built environment analysis, Pearson's correlation will be helpful in the study's conclusion.

Pearson's Correlation

A comprehensive data table encompassed the risk zone categories, viz. very high, high, moderate, low, and very low; ward-wise population; built-up share in per cent in the ward; open space in per cent in the ward; average connectedness, average angular connectivity, average segment length, and average integration of streets in each sample wards. Finally, Pearson's correlation was calculated to identify the impact of the availability of open space and the integration of streets on the possibility of spreading infectious diseases.

Analysis and results

The sample wards identified were Ward 42, Burrabazar; Ward 66, Tangra and Topsia; Ward 68, Ballygaunge; Ward 71, Bhowanpure; Ward 95, Tollygunge and Golf Green; and Ward 92, Dhakuria. As preliminary data indicated, wards 66 and 68 had larger populations, suggesting denser residential settlements and higher urban activity. On the other hand, there were sizable open spaces in wards 71 and 95, which meant a balanced development of green and built-up land parcels.

The varied share of built-up areas indicated differing infrastructure and urban development degrees in all the sample wards. For example, Ward 42 had the most significant share of built-up area, with 40 per cent. On the other hand, Wards 71 and 95 had the most significant share of open spaces (including roads, open plots, and set-back areas of the occupied plots).

Figure 2 : Built-up and Open Area Representation of Different Study Wards

In network dynamics, segment analysis done in DepthyMapX considered the dynamism of street connectivity patterns in terms of node connection, angular connectivity, road segment lengths, and network integration. Knowing these metrics is essential to understanding network dynamics. Understanding these elements improves overall network resilience and efficiency while facilitating optimal connectivity.

The analysis results demonstrate that the studied wards in Kolkata, including Bhowanipore and Dhakuria, have different average segment lengths, highlighting the intricate details of urban planning and connection. While longer segment lengths in Burrabazar indicate potential broad street configurations, shorter segment lengths in Dhakuria and Tollygunge reflect a possibly denser urban fabric. The Connectivity attribute values represent the segment connectivity, which measures how well the segments or edges are connected in the overall street network graph. The data obtained as the average values, as shown in Table 2 for selected wards of Kolkata, demonstrates values that are almost close to Bhowanipore and Dhakuria. Lower values in Tangra and Topsia wards suggest that the urban spaces are less integrated, while higher values in Burrabazar indicate spatial connectivity.

Table 1 : Ward Wise Distribution of Population, Built-up Percentage, Open Area Percentage, and Risk Zones

Ward No	Area	Population	Built-Up Percentage	Open Area Percentage	Risk Zone
71	Bhowanipore	29922	18	82	Low Risk
92	Dhakuria	36450	31	69	Moderate
95	Tollygunge and Golf Green	26737	30	70	Low Risk
68	Ballygunge	20724	35	65	Lowest Risk
66	Tangra and Topsia	98024	35	65	Highest Risk
42	Burrabazar	21746	40	60	Highest Risk

A higher number of angular connectivity values implies more angularity. In this context, as shown in Table 2, the lower values are obtained in the Tangra and Topsia areas, suggesting straighter streets with few changes. In comparison, higher values in Burrabazar show potentially complex configurations. At the same time, the other wards show almost the same configurations.

Finally, the street's level of network integration or centrality was evaluated. It measures how accessible and meaningful a particular location is inside the analyzed urban network. The number of direct connections crossing or passing through a specific place determines integration values. Greater accessibility and centrality are often indicated by higher integration points, indicating that the location is an important hub or node within the urban fabric. As seen in Figure 3, Ballygunge and Tollygunge suggest better connectivity and centrality, potentially indicating a good street network. Conversely, lower integration values in Tangra and Burrabazar may indicate less integration, while Bhowanipor and Dhakuria seem to have a moderate integration score, as shown in Table 2.

Table 2 : Segment Analysis: Average Values of Attributes after Conducting Network Analysis

Ward No	Area	Segment Length	Connectivity	Angular Connectivity	Integration
71	**Bhowanipore**	**29.5150**	**2.81128**	**1.40813**	**221.194**
92	**Dhakuria**	**20.0605**	**2.94347**	**1.48630**	**281.530**
95	**Tollygunge and Golf Green**	**23.3396**	**2.80272**	**1.44233**	**300.075**

Ward No	Area	Segment Length	Connectivity	Angular Connectivity	Integration
68	Ballygunge	24.3498	2.86731	1.37906	317.998
66	Tangra and Topsia	25.9315	2.53295	1.11550	165.921
42	Burrabazar	37.1553	3.01873	1.50284	88.349

Figure 3: Integration Attribute Results using DepthMapX: Network Analysis of Study Areas

Finally, the risk zone categories were assigned numeric values to check for statistical correlation. Since the risk zones were categorized into five distinct categories, the risk possibilities were scaled from 0 to 100 per cent. The lowest possibility was assigned a weightage of 20 per cent, whereas the highest was 100 per cent, with an increase of 20 per cent with each category. (Refer to Table 3)

It is seen (Refer to Table 4) that the factors which are having a direct relation are the population of the area (with an increase in population, the risk factor increases), the built-up area percentage (with an increase in built-up, the risk factor also increases), open area percentage(with the increase in open area percentage the risk factor decreases). In street network attributes, while the segment length, connectivity, and angular connectivity show almost negligible relation, the essential factor of integration that also employs regard to the accessibility and centrality shows a high relation to the risk factor of the wards, i.e. with an increase in the integration value the risk factor decreases.

Table 3: Correlation among Different Variables

Variables	Population	Built-Up	Open Area	Segment Length	Connectivity	Angular Connectivity	Integration	Risk Zone
Population	1	0.125	-0.125	-0.17	-0.863	-0.908	-0.294	-0.573
Built-Up	0.125	1	-1.000	0.215	0.149	-0.077	-0.339	-0.51
Open Area	-0.125	-1.000	1	-0.215	-0.149	0.077	0.339	0.51
Segment Length	-0.17	0.215	-0.215	1	0.281	0.154	-0.844	-0.492
Connectivity	-0.863	0.149	-0.149	0.281	1	0.943	-0.003	0.176
Angular Connectivity	-0.908	-0.077	0.077	0.154	0.943**	1	0.146	0.313
Integration	-0.294	-0.339	0.339	-0.844*	-0.003	0.146	1	0.871
Risk Zone	-0.573	-0.51	0.51	-0.492	0.176	0.313	0.871*	1

(*) the correlation is statistically significant at the 0.05 level ($p < 0.05$), meaning there's less than a 5% chance that the correlation happened randomly.

(**) indicates a stronger significance level, typically at the 0.01 level ($p < 0.01$), meaning there's less than a 1% chance that the result occurred randomly.

Table 4: Relation of Variables with Risk Factor

Variables (with increase)	Risk Factor
Population	Increases
Built-up Percentage	Increases
Open area Percentage	Decreases
Segment Length	Negligible Change
Connectivity	Negligible Change
Angular Connectivity	Negligible Change
Integration	Decreases

CONCLUSION

Increasing urbanization and shrinking lung spaces in cities impose several challenges for sustainable development. These challenges create hurdles not only for social or economic growth but also for the healthy growth of the town. The study is a pilot attempt to understand the role of the built environment on the well-being of urban dwellers. The study demonstrated the relationship between COVID-19 spatial distribution patterns and attributes of the built environments of the settlement. As one of the country's densest cities, Kolkata was taken as a case. The study is a pilot attempt to undermine the association of infectious disease spread over a space with its built characteristics; therefore, six wards were considered in the current study. Wards' geographical area, population, built-up share, open share, and street connectedness were the considered attributes; connectedness was assessed using depth analysis based on segment length, connectivity, angular connectivity, and integration of street layout. The risk zone identification was done based on already existing literature and resources. Finally, a correlational study was conducted to unveil the role of the built environment on urban wellness.

The results highlight that the hypothesis assuming the existence of the influence of the built environment on urban wellness is true. The correlational study indicates that the rise of population concentrations within a geographical extent creates a more vulnerable situation regarding dwellers' declined health. For example, in this case, the population increase posed a higher risk of spreading the pandemic in the particular ward. Similarly, higher built-up densities also catered to higher probabilities of infection spreading in the region. Hence, it is inferred that the city zones with higher population densities are more prone to the challenges of urban wellness. Alternatively, increasing open spaces reduces the risk of spreading infectious diseases in such city zones. Finally, the settlements with higher degrees of street integration are less prone to pandemic spread within the settlement.

To summarise the practical implications of the results, we can state that this study will help prioritise open areas regardless of how densely inhabited the area is. Urban planners should focus on improving road connectivity and integration. The study suggests that the effective network of roads and pathways supports reducing the risk of community-level virus propagation, such as during the last COVID-19 pandemic. It is possible to do this by designing for increased public health resilience and equipping it to combat such spreads. The findings highlight the importance of promoting physical and mental health in the built environment. While discussing the studies, real-world application support in policy formulation is critical. Informed findings could be used to construct evidence-based policies. It has proved essential to emphasize a particular percentage of green open space by reinterpreting prior street relationships. Therefore, similar results will help establish informed zoning regulations.

Future research could look at the long-term effects of green and open spaces on mental health and comparative studies on spatial equity and access to green spaces across socioeconomic groups to see how they affect improved public health outcomes. Studies on how urban form and infrastructure can be resilient in future pandemic conditions. Further AI-powered models are being developed that use space syntax analysis and socioeconomic and health data to forecast urban well-being outcomes and health risks depending on spatial configurations.

In a nutshell, the study indicates that in a rapidly urbanizing world, it becomes essential for planners and policymakers to understand the importance of urban well-being and the role of the built environment in influencing the same. Increased urban wellness results in better efficiency of the city system, as the city's physical environment and dwellers are healthy. The study concludes that, with the aim of health sustainability, dense settlements must be planned with sufficient open space share and maximized pathway integrations. Such associations require further investigations by incorporating variables like income categories, housing typologies, and location attributes and applying more advanced cohort techniques.

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Exploring Biophilic Design: Bringing Nature into the Buildings

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Abstract— In current scenario, urban environments are marked by the absence of green spaces and the overuse of artificial materials which can lead to a range of issues like stress, anxiety, and lack of well-being. Man-made system and natural system can co-exist in a respectful relationship rather than one of dominance. Rich, rewarding and long-lasting results of both the systems are possible, but only if the association changes both partners such that they are more suited to one another. Minor adjustments to people and their surroundings trigger this reciprocal adaptation process, but a more deliberate design process is also possible with Biophilic Design. This paper describes "Biophilic Design" theoretically and is based on the urban ecological knowledge and sustainable principles that underlie biophilic design, which may influence architects, builders and other stakeholders in the design of built environment. The impact of urbanization on biodiversity has been thoroughly researched and biophilic design approach could be used to manage the complex and ever-changing character of cities. The National Building Code of India provides guidelines for construction of structures as per fourteen principles of biophilic design. The paper also examines the benefits of biophilic design and also explains theories related to biophilic design such as "Biophilia", "Biophilia Hypothesis", "Attention Restoration Theory (ART)", "Stress Reduction Theory (SRT)" and "Perceptual Fluency Account (PFA)". Additionally, the paper also explores biophilic design of various buildings including Development Alternative World Headquarters, New Delhi; Biowonder, Kolkata and Paradox, Pune. Biophilic design seeks to bridge this gap by adopting natural features into the built environment to create healthy spaces. The objective of biophilic design is to emphasize the human connection with nature by integrating buildings with the local environment. In conclusion, this paper argues that biophilic design is an essential approach to create sustainable and healthy built environments that allow people to reconnect with nature in a world that is becoming increasingly disconnected from the natural world.

Keywords: Biophilic, Biophilic Hypothesis, Stress Reduction, Attention Restoration, Biophilic Principles

INTRODUCTION

Man made system and natural system can co-exist in a respectful relationship rather than one of dominance. Rich, rewarding and long-lasting results are possible, but only if the association changes both partners such that they are more suited to one another. We can design new habitats that are ecologically sound, visually pleasing and financially lucrative with our knowledge and feeling of responsibility. Minor adjustments to people and their surroundings trigger this reciprocal adaptation process, but a more deliberate design process is also possible."

The term "biophilia" was coined by Erich Fromm (1964). The biophilia notion was ultimately widely accepted twenty years after it was initially proposed. "Biophilia," according Edward Wilson, is "the innate propensity to emphasise life and lifelike processes" (1984, p. 1). Wilson (1993) created the "biophilia hypothesis" to contend that people's emotional ties to "life" survived their departure from their ancestors' natural home and subsequent relocation to an artificial new one. He emphasised that biophilia refers to "the innately emotional link of human beings to other living organisms". Embodying "hereditary" characteristics and functioning as a "learning rule," it provides a clear lens to understand nature. (JulietteBekkering, 2022).Building has regularly drawn inspiration from natural materials, forms, and processes throughout history. Perhaps the most prominent example of this influence may be seen in ornament, which usually features images that are very similar to or suggestive of the animal and plant kingdom. (Joye, 2007).

METHODOLOGY

The data related to this paper has been drawn from secondary sources. Published and unpublished reading material like research papers, reports, dissertation, working papers and case studies reports are referred to prepare this research paper. The first section of paper presents conceptual definition of biophilic design incorporating natural elements, maximizing natural light, using natural shapes, creating multi-sensory experiences into the built environment to create a healthier and more productive space for people. Further this research article presents various theories of Biophillic design, and also analyze the case studies with reference to biophilic design principles.

Definition of biophilic design

"Biophilic design is an innovative way of arranging the places that we inhabit, in a manner that includes natural materials, natural light, and other elements of nature" (Fromm, 1964). The objective of biophilic design is to bring nature back into the built environment and to emphasize the human connection to nature by integrating buildings with the local environment. Biophilic design aims to create a healthier and more productive environment for people by incorporating nature into buildings. The National Building Code of India provides guidelines for construction of structures, including biophilic design elements such as "environmental features, natural shapes and forms, natural patterns and processes, light, and space" (NBC,2016). Biophilic design can be incorporated into architecture design by using botanical shapes and forms, creating visual relationships to nature, and establishing multi-sensory experiences.

The Benefits of Biophilic Design:

There are numerous benefits to biophilic design, both for individuals and for society as a whole. Research has shown that exposure to nature can have a positive impact on mental health and well-being, reducing stress, anxiety, and depression. Biophilic design can also improve physical health by promoting movement and reducing the risk of chronic diseases such as obesity and diabetes. Additionally, incorporating natural elements into the built environment can improve air quality, reduce noise pollution, and improve the overall sustainability of the built environment.

Applications of Biophilic Design:

Biophilic design can take many forms, from incorporating natural materials and colors, to integrating greenery and water features, to creating spaces that allow for natural light and fresh air. One example of biophilic design is the use of living walls or green roofs, which can improve air quality and provide natural insulation. Another example is the use of natural materials such as wood, stone, and bamboo, which can create a calming and soothing environment. Additionally, creating spaces that allow for natural light and fresh air can improve overall health and well-being.

Biophilic Design approach a step next to Biomimicry and Sustainable Architecture

Biophilic design, Biomimicry, and Sustainable Architecture are three different approaches to design, each with its own unique focus and principles. Broad definition and scope of these three terms are described in this section.

"Biophilic Design is a design approach that seeks to incorporate nature and natural elements into the built environment, with the aim of improving human well-being and connection to nature". Biophilic design focuses on creating spaces that allow people to connect with nature, such as incorporating natural light, views of nature, and natural materials.

Biomimicry is an approach that seeks to learn from and emulate the natural world in order to create sustainable and innovative solutions to design challenges. "This approach is based on the idea that nature has already solved many of the problems" that we face in design, and that by studying and imitating natural systems, we can create more sustainable and efficient designs.

Sustainable Architecture, on the other hand, is a "design approach that seeks to create buildings and structures that minimize their environmental impact and maximize their efficiency and sustainability". Sustainable architecture focuses on using renewable energy sources, reducing waste and emissions, and minimizing the use of non-renewable resources.

In summary, biophilic design focuses on creating spaces that allow people to connect with nature, biomimicry seeks to learn from and imitate the natural world to create sustainable designs, and sustainable architecture aims to minimize the environmental impact of buildings and structures. Following table describes scope of Biophilic, Biomimicry and Sustainable Architecture.

Theories related to biophilic design approach

This section describes various theories related to Biophilic Design approach such as "Biophilia", "Biophilia Hypothesis", "Attention Restoration Theory (ART)", "Stress Reduction Theory (SRT)" and "Perceptual Fluency Account (PFA)".

Biophilia

The term "biophilia" refers to a love of life or living things. According to Biophilia theory, humans have a compulsion to connect with the environment around them and are predisposed to do so. This tendency is innate, and although we tend to draw toward it, we can also be opposed to it. For instance, while it may be natural to want to be outside on a pleasant summer day, we also do not want to be in the vicinity of a dangerous snake. Biophilic design reveals how the built environment could—and should—be fundamentally rethought considering how the human brain functions." (Vagal, 2020).

Biophilia Hypothesis

"The biophilia hypothesis claims that when people are separated from their natural surroundings, their innate learning principles remain intact. However, they continue from generation to generation, atrophied and sporadic in their manifestation amid the artificial new surroundings into which technology has thrust humans." (Wilson, 1993) "Biophilia is thought to have evolved through a biocultural process, in which hereditary learning principles have developed culture while the genes dictating the trait spread through natural selection in a cultural setting. This process, in which a certain genotype increases the likelihood that a behavioural response would occur, is known as gene-culture coevolution. In turn, if this behaviour improves one's chances of surviving and having children, the genotype will spread throughout the population and the behaviour will become more common." (Wilson, 1993)

Attention Restoration Theory (ART)

"Briefly stated, the Attention Restoration Theory (ART) postulates that being in nature can help us focus and increase our capacity for concentration in addition to being enjoyable." (Ohly, 2016)

According to ART, a healing environment has four essential characteristics:

1. Being absent (the setting is perceived to be separated from daily stressors)

2. Subdued Fascination (the ability of an environment to capture attention without effort)

3. Amount (the environment is rich and coherent enough to simulate a whole other world)

4. Suitability (the ability of an environment to fit the goals and desires of a person)

Stress Reduction Theory (SRT)

This theory defines stress as the process of producing human stimuli in response to events, environmental characteristics, or circumstances that are perceived as a danger to a person's wellbeing. This intensifies the bad feelings.

Perceptual Fluency Account (PFA)

PFA functions as the meeting point of ART and SRT Theories. The conclusion of this theory holds that a natural setting, which predominates in built environments, is one in which the human brain can perceive and produce stimuli more frequently and fluently than an urban context, which is less natural. As a result, having smooth conversations minimises mental strain, helps the brain focus again, and eventually relieves stress (Associates, 2020).

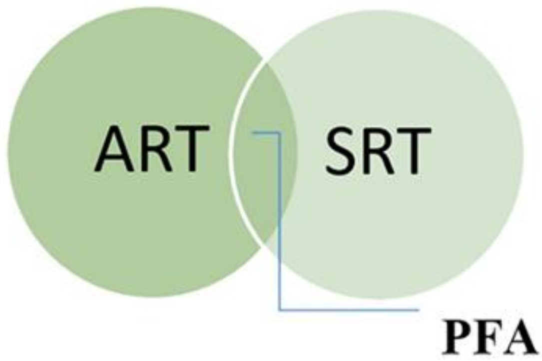

Figure 1: Diagram showing Attention Restoration Theory and Stress Reduction Theory forming an intersection at PFA. Source: (Architects, 2020)

Overall, the theories related to biophilic design suggest that incorporating natural elements into the built environment can have a positive impact on human health and well-being.

Fourteen patterns of biophilia

There are fourteen patterns of biophilic design, as identified by Stephen R. Kellert and Elizabeth F. Calabrese in their professional work. These fourteen patterns are a part of three major categories of

Biophilic Design. The three major categories are – Nature in space, Natural Analogues and Nature of the space. These three major categories are further divided into sub-categories as explained in following:

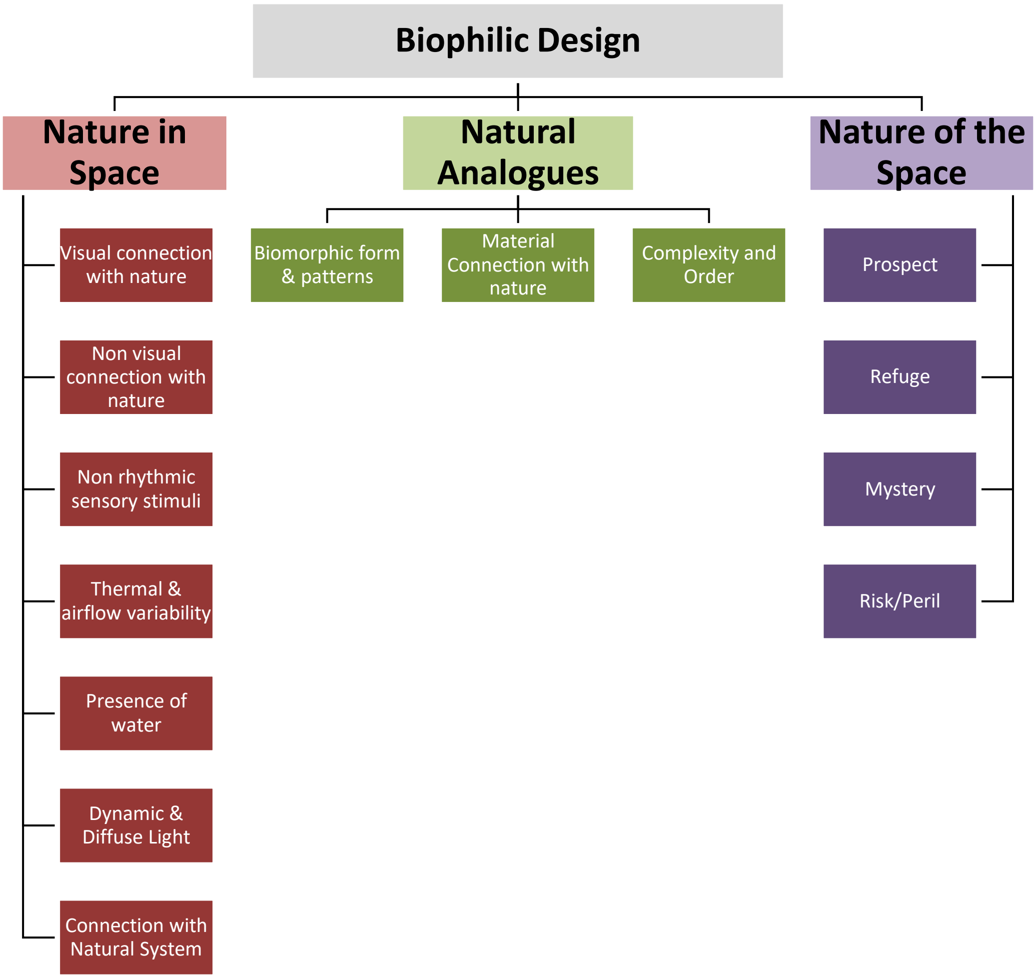

Figure 2: Fourteen Patterns of Biophilia

First Major Category–"Nature in Space"

"Nature in Space-addresses the direct, physical, and ephemeral presence of nature in a space or place. This includes plant life, water, and animals, as well as breezes, sounds, scents, and other natural elements. This category has seven sub-categories which are Visual Connection with Nature, Non-Visual Connection with Nature, Non-Rhythmic Sensory Stimuli, Thermal & Airflow Variability Presence of Water, Dynamic & Diffuse Light and Connection with Natural Systems".

Second Major Category –"Natural Analogues"

"Natural Analogues addresses objects, materials, colours, shapes, sequences, and patterns found in nature, manifest as artwork, ornamentation, furniture, décor, and textiles in the built environment. This category has three sub-categories which are Biomorphic Forms & Patterns, Material Connection with Nature and Complexity & Order".

Third Major Category – "Nature of the Space"

"Nature of Space-addresses spatial configurations found in nature. This includes our innate and learned desire to be able to see beyond our immediate surroundings. The strongest Nature of the Space experiences are achieved through the creation of deliberate and engaging spatial configurations with patterns of Nature in the Space and Natural Analogues. (Browning, 2014). This category has four sub-categories which are Prospect, Refuge, Mystery and Risk/Peril".

Case study of buildings

This section presents case studies of three buildings i.e. Development Alternative World Headquarters, New Delhi; Biowonder, Kolkata and Paradox, Pune within the frame work of Biophilic Design approach.

Development Alternative World Headquarters, New Delhi

"The Development Alternatives World Headquarters is located in New Delhi. This building aims at Zero Emissions. It is described as a living ecosystem: a balance of natural and man-made processes, employing environment- friendly energy, material and water management methods. It is already becoming the benchmark for green buildings in India. Development Alternatives believes that this newly reconstructed Headquarters building will set a standard for responsible construction practices in India that will rely on the use of alternative, eco-friendly and cost-effective methods, technologies and solutions. This building incorporates some of the fourteen patterns of Biophilic design approach. Green clothing concept is applied here, the building is covered with plants on its eastern and western side and on its roof to reduce the amount of heat gain from the openings on those façades. Plantation is done in the courtyard with some small water body, to get cool breeze in the summer".

Biowonder, Kolkata

"BIOWONDER, located in Kolkata is the first biophilic corporate park of East India that attempts to go for mixed used development. It offers multifarious opportunities for work, housing, recreation, entertainment and public facilities. Bio wonder is an attempt to create one such precedent that would help to establish this connect within the larger working environment that humans inhabit. Biophilic design facilitates other connected values such as energy efficiency, proliferation of green elements and increased performance and productivity at the workplace".

The makers of Bio wonder have been influenced by the lack of greenery, sunlight and fresh air which have an adverse impact on the human mind and body. The average human being spends 65% of their lives in the closed box-like office spaces, which makes life stressful and unhealthy. So, the makers of Bio wonder decided to go a step further from a mere green building to create a unique and sustainable biophilic workspace that will help people flourish and perform at their workplace with greater passion and excellence.

"The entire ground floor area of the site is redeveloped as terrace gardens in the building profile. Designed to provide social coherence, the terraces are well connected to each other and enable a green layer. The urban greenery is increased to reduce the effects of the heat island".

Paradox, Pune

"CORE Architecture has designed an innovative and lively contemplative space for the Pune headquarters of German manufacturing India Ltd. The architect created a comfortable, biophilic microclimate for the workspace by utilizing passive cooling design principles which led to substantial reductions in energy consumption. The project, Paradox, is named rightly so as the concept was to build calm, yet dynamic and vibrant space all at the same time. Other design strategies include the use of golden elements and homogenizing nature with the architecture. The project structure can be functionally split into two East-West oriented halves, both with longer faces towards the North and South orientation. The common zone between the two halves has been imagined as a valley linking two rock outcrops which consequently creates a microenvironment with a breeze lowering the building's ambient temperature".

"In terms of facades, each orientation follows a separate design treatment. While the South face was treated with operable louvers and shading systems, the East and West facades had few to nil openings due to the harsh, horizontal morning and evening sun. The North and South facades provided all the necessary lighting for the workspaces. The elevator within the building was replaced with a verdant mound to encourage walking and create a characteristic and experiential circulation route. Additionally, the central area offers views of a coconut plantation and connects to a reflecting pool with stormwater collection capabilities and the overflow for recharging groundwater. Communal activities are scattered in the central area to create a lively layout rather than a static spectacle. The overall architecture expresses a minimalist aesthetic and stays true to its meditative appeal through biophilic integrations".

CONCLUSION

Currently, it is unknown how certain procedures link to health benefits; this connection has not yet been established by science. The boundaries dividing different approaches are also blurry, and it is frequently important to apply discretion to choose the optimal course of action. Time constraints prevented a complete study that would have shown how the inhabitants responded and how various elements impacted their degree of wellbeing.

"The importance of contact with natural elements for human health and well-being is emphasized by biophilia. Regenerative architecture takes a holistic approach, upholds the notion that we are nature and that we can co-evolve human and natural requirements to create structures that are integrated into their surroundings' ecosystems". The notion that humans can be benefited from nature (biophilia) and that human actions can have a positive impact on nature constitutes a "win-win situation" (restoration and regeneration). The improvement and regeneration of living systems is the common objective of these innovative design principles, which work at several levels and are not distinct from one another: linking humankind and nature. The study of literature has shown that nature and aspects of nature may significantly affect human health and well-being. Additionally, it has been found that both direct and indirect exposure to nature has a significant influence on people's perceptions of symbolic nature. This study implies that designers should try to situate offices close to or inside natural areas, promote the usage of routes and mobility within these areas, maximise the supply of sunshine and vistas, and consider the spatial design and evolved human features of nature. Where direct touch with nature is not available, exposure to indirect nature—such as wood and potted plants—can still be beneficial. The case examples demonstrate how the theory may be used successfully and realistically.

The study of literature has shown that nature and aspects of nature may significantly affect human health and well-being. Additionally, it has been found that both direct and indirect exposure to nature may lessen feelings of environmental stress and offer moments of concentration that are restorative.

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CONFLICTS OF INTEREST

No conflicts of interest was declared by the authors.

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Study of Urban Heat Island Effect Through the Impact of Regulatory Norms Causing Changes in Urban Scape: Case of Girgaon, Mumbai

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Abstract— India is expected to experience a significant rise in its urban population by 2050. The urban heat island effect emerges as a crucial environmental issue within the country that requires attention. The swift urbanization process contributes to this effect through various factors, such as the absorption and retention of heat by buildings and pavements, diminished vegetation, and the emission of waste & heat from vehicles and structures. The paper investigates through case studies how the built & unbuilt fabric in the neighbourhood creates urban heat island effect in dense neighbourhoods in cities of today.

This phenomenon, known as the urban heat island effect, stems from the rapid alterations in urban surfaces, leading to elevated surface and air temperatures within the urban boundary when contrasted with the neighbouring rural areas. The paper questions development trends of today and tries to identify strategies to facilitate reduction of the urban heat island effect at microclimatic level. The paper will try to establish the co relationship between the development regulations & built urban fabric with respect to the urban heat island effect. The exploration of the research is not limited to the findings in the study but aspires to create recommendations for policy guidelines or strategies to develop better building codes to reduce urban heat island effect in neighbourhoods.

Keywords: urban heat island effect, urban neighbourhoods, liveable environment, development regulations, built urban fabric.

INTRODUCTION

An urban heat island, or UHI, is a metropolitan area that's a lot warmer than the rural areas surrounding it. Heat is created by energy from all the people, cars, buses, and trains in big cities: places that have lots of activity and lots of people. The urban heat island is caused when urban areas have higher temperatures than the surrounding countryside is mainly related to the heat capacity of materials.

Numerous studies have shown that urbanization can produce radical changes in the radiative, thermodynamic, and water processes of the land surface and modify local climate (J.F.He, J.Y.Liu, D.F.Zhuang, W.Zhang, and M.L.Liu; 2006.). Mumbai has undergone this change after the redevelopment schemes were introduced in 1991. The city of Mumbai has undergone rapid transformation after 1991; the island city of Mumbai was saturated with urban development till this time. The old structures were dilapidating due to lack of maintenance. Due to the change in development regulations after the introduction of redevelopment schemes in 19991, the island city started undergoing rapid changes. The cessed buildings (built before 1945) were open to redevelopment creating an opportunity for growth. These schemes caused a shift in the urban fabric of the region which consisted of predominantly chawls and walk up apartment buildings. The scheme allowed the developers to construct 3 times the earlier permissible built area on the same plot of land.

This created a denser urban fabric with the pressure increasing on the existing urban infrastructure

The swift urbanization process contributes to the urban heat island effect through various factors, such as the absorption and retention of heat by buildings and pavements, diminished vegetation, and the emission of waste & heat from vehicles and structures. Mumbai is facing this challenge as are many cities globally. In order to understand the effects of the phenomenon, firstly we need to study the reasons & outcomes of this phenomenon.

Scope and Methodology of Research

The region of study in the research paper is limited to one neighbourhood in the city of Mumbai as an example. The microclimate of the neighbourhoods is the determinant factor in changing the overall climate of the city. The evolutions in the city at neighbourhood level impact these changes in any urban settlement. The changing urban fabric is the outcome of the development control regulations & building codes of the city.

Mumbai has transformed from a small fishing village to the metropolis in the last century. The last two or three decades has witnessed the transformation of the city fabric due to exponential growth & scarcity of land in the core city area The neighbourhood selected for the study are taken considering the significant changes in the urban fabric of the region.

Data collection will encompass the mapping of changes in land cover of the neighbourhood. They include comparative studies of parameters affecting the development in the neighbourhood and its impact on the climatic conditions. The parameters for the study will be defined by studying the policies applicable to the study area.

The outcome of the research will be also require understanding prevalent examples of research that has been conducted & the changes in the building codes & strategies implemented to the neighbourhood.

LITERATURE REVIEW

The research papers studied for this research comprise of studies done to understand the phenomenon of urban heat island effect on urban developemnt. Through the papers as stated below the following outocmes are taekn from the study conducted by other researchers to carry forward this study.

The research papers studied for this research comprise of studies done to understand the phenomenon of urban heat island effect on urban development. Through the papers as stated below the following outcomes are taken from the research conducted by others to validate the co-relationship as suggested in the aim of this paper.

In this research paper, the authors adhere to prove that the term, UHI describes the phenomenon that urban temperature is commonly higher than that of surrounding suburbs, because that solar radiation is stored in urban canyon at daytime, and is released in the form of long-wave heat radiation at night time. Previous studies show there is a strong co-relation between UHI and Sky View Factor (SVF), which constructs a potential linkage between UHI and urban forms. As cities grow denser and hotter, urban form manipulation strategies for mitigating heat island become an increasingly important challenge for urban planners and designers. A considerable body of research has revealed that heat island is closely related to urban geometry and urban materials. Conversely, urban materials may be improved and enhanced by means of increasing green plant coverage, water bodies, and using lighter coloured and low thermal storage materials to reduce UHI impact (Youpei Hua, et al, 2016)

This research says that global warming can be partitioned into (1) the urban heat island effect, (2) the effect of deforestation, (3) the effect of secular micro-climate shift, (4) the influence of general global warming with particular reference to the tropics. The intensity of the urban heat island (UHI) is directly related to the rate of urbanization, land-use patterns, and building density (J.F. He et al; 2006).

The research based in the city of Chennai assesses the relationship of various urban factors and the intensity of urban heat island effect. It further reinforces the relationship between the air temperature increase in urban areas and the development factors such as the built-up spaces, vegetation, parking lots etc. the research tries to prove that areas with dense vegetation recorded lesser air temperatures and dense built area along with heavy traffic recorded higher temperatures through mobile recordings of urban air temperatures during summer and winter. The results indicate the existence of heat island effect in the city of Chennai with increasing air temperatures in a radial fashion from the suburbs towards the city centre where the mean max UHI intensity reaches 2.48°C during summer and 3.35°C during winter. (Devadas M. et al, 2009).

This paper reviews various UHI mitigation strategies and their effectiveness in cooling the urban environment and propose a set of recommendation based on research and analysis. Broadly, the mitigation strategies have been divided into (i) Roof strategies, (ii) non-roof strategies, and (iii) covered parking strategies. The use of several UHI mitigation measures simultaneously has a greater impact on reducing the urban temperature and thus the heat island effect could be mitigated. Heat islands increase cooling loads in the summer, which tends to increase energy consumption and produce more greenhouse gases, thus adding to the pollution in turn affecting the rising temperatures of the area. The study highlights each mitigation strategy and its importance along with a set of recommendations for India that can be directed at the government level to reduce the UHI effect (Khare V. et al, 2021).

This research summarises that cities are vulnerable to the dual effects of both climate change and urbanization. Urbanization alone has led to an overall 60% enhancement in warming in Indian cities, with eastern Tier-II cities leading the way. The research validates the need for a differential approach to combat urban warming effectively. (Sethi, S.S. et al, 2024).

The present paper evaluates the trends of UHI studies in Indian cities and its outreach till 2018. Heat Island classification, methods of studying UHI in India and their limitation are discussed. Eventually a comparison of new trends of UHI studies in the world and where India lacks its growth in UHI research are included in this paper. One of the findings is that numerical modelling studies are very limited in India in this field and more focus in this area is required (Veena K. 2020)

The authors of the present paper carried out a study on the city of Jaipur which focuses on the on reduction of heat island effect in urban areas along with compatible strategies in Indian conditions partly to address higher energy consumptions and partly to reduce other negative impacts being caused on account of such heat island effects (Neel Kamal. (2021).

As per this research paper, cities around the world have seen a spike in the urbanization rate through extensive conversion of natural landscape which has resulted in the changes in the local temperature. The paper further states that study on Urban heat islands has been done extensively in India since 2000. In this study the author has used computer application and generated thermal imagery to prove the transition in the temperature on the urban climate (Zeba et al, 2023).

This paper aims at measuring canopy layer heat island (CLHI) in a compact city of Nagpur, India using local climate zone (LCZ) classification. It also accesses the inter-LCZ temperature difference within the city and identifies critical areas that require intervention to curb heat island. The methodology describes LCZs mapping, data collection technique using fixed station points and mobile traverse survey conducted during the month of December 2015 and February 2016 of winter season. The paper adopts rigorous data filtering technique to avoid the errors in reporting UHI of cities having compact and heterogeneous built form like Nagpur. The study also reports thermal variation between traditional LCZs and the LCZs with subclasses. The study concludes with identification of critical LCZs in terms of IUHI and suggests the need for intervention (Kotharkar R., 2018)

In this paper, the negative impact of urbanization over a time and its effect on increasing trend of temperature and degradation of urban ecology was assessed using the Landsat thermal data and field survey of Lucknow city, India. Land surface temperature has been carried out using various methods. Results indicated spatial distribution the spatial distribution of the land surface temperature was affected by the land use-land cover change and anthropogenic causes. The mean land surface temperature difference between the years 2002 and 2014 was found is 0.75 °C. The paper clearly states the areas that are affected due to certain urban development trends in the city. The present study provides very scientific information on impact of urbanization and anthropogenic activities which cause major changes on eco-environment of the city (Singh, P. 2018).

According to Siddiqui A. (2018) study investigates the day/night seasonal and annual changes and trends in land surface temperature (LST) and surface urban heat island intensity (SUHII) during the last two decades for three Indian cities (Lucknow, Kolkata and Pune) with distinct urban, physiographic and climatic setting. The urban (contiguous built-up) and non-urban (surrounding rural) areas are delineated by applying city clustering algorithm on MODIS Land Cover datasets of 500 m spatial resolution. The findings show that the diurnal temperature range (DTR) has decreased from 2001 to 2018 due to higher increase in night time LST as compared to daytime. The study highlights that geographical, physiographic and climatic setting along with anthropogenic processes in urban and its surrounding non-urban areas are critical towards understanding the causative factors in exacerbating the phenomenon of urban heating. (Siddiqui A.2018)

An integrated use of Landsat thermal data sets of year 2000 and 2013, field data and meteorological observation were used to assess the temporal changes in rising trends of urban heat island (UHI) in Noida city, India. In order to study the relationship between UHI and land cover, statistical analysis was performed between temperature and Normalized Difference Built-up Index (NDBI), Normalized

Difference Vegetation Index (NDVI), Albedo and Emissivity. During 2000, the total built up area was 28.17 km2 which it further increased to 88.35 km2 during 2013. Over the period of thirteen years from 2000 to 2013 it was observed that the built-up area has increased by 26.94% of the total area (203 km2). Results showed that the change in temperature was mainly due to increase in impervious areas. The results of this study will be useful to the urban planners and environmentalists in formulating local policies. (Kikon 2016)

The outcome of this research can be utilized for the formulation of SUHI mitigation strategies and maintaining urban thermal comfort in Delhi and cities with similar geographical conditions. “The land use/land cover (LU/LC) change and its impact on the surface UHI intensity (SUHII) and urban thermal comfort has been analysed using Landsat datasets and geographically weighted regression (GWR) in Delhi metropolitan city. The result shows that the built-up area has increased from 315.18 to 720.24 sq. km in Delhi during 1991 to 2018 while other LU/LC types have declined. This has resulted in a substantial increase in LST and SUHII. The minimum, maximum and mean SUHII has increased by 1.26 °C, 4.6 °C and 1.18 °C during 1991 to 2018 and hence, the thermal comfort has declined in the city. The GWR analysis showed that the performance of GWR model was very good in showing the association between LU/LC and SUHII and the LU/LC pattern has significant impact on SUHII.” (Shahfahad 2022))

As per the research paper, the relationship of land surface temperature (LST) between percent impervious surface area (%ISA) and elevation has been investigated in this study. “Significant surface urban heat island (SUHI) has been observed in the Chandigarh study area from the analysis of five years land surface temperature (LST) data from 2009 to 2013. UHI intensity over the study area varies with seasons. Average annual UHI intensity from 2009 to 2013 varies from 4.98 K to 5.43 K and overall average UHI intensity has been observed to be 5.2 K. The maximum value of UHI index has been found to be 0.93. Pixels with average value of UHI index more than 0.90 have been considered as hot spots (HS). But in this study, as the elevation increases, rising trend of LST can be observed. Negative relationship between LST and Elevation scatterplots has been observed in high altitude areas during monsoon season compared to summer and winter seasons. Besides other factors elevation also plays a significant role in LST dynamics and spatial distribution of LST” (Mathew A. 2016).

Policies: Redevelopment scheme for Cessed building DCR 33(7)

The following are the guidelines given for redeveloped properties under this scheme:

FSI: 2.5 for cessed buildings (the Floor Space Index shall be 2.5 on the gross plot area or the FSI required for rehabilitation of existing tenants plus incentive FSI as specified in Appendix-III, of DCR amended in 2012, whichever is more).

FSI : 4 for cessed buildings under urban renewal scheme (the FSI shall be 4.00 or the FSI required for rehabilitation of existing tenants/occupiers plus incentive FSI as given in Appendix-III-A, of DCR amended in 2012, whichever is more.)

Open space: for plots with area less than 1001 sq m, not open space is to be provided.

Marginal open space: 3-4.5 mts. on all sides. Plots exceeding 600 sq.mts. and having height more than 24 m, at least, one side other than road side, shall have clear open space of 6 m at ground level, accessible from road side, for plot size upto 600 sq.mt., 1.5mt open space will be deemed to be adequate

Height restriction: There are no height restrictions for this region for redevelopment projects of cessed buildings. The structure can go to 60 mts. after which the high rise regulations apply.

Parking requirements: as per DCR the parking requirement are relaxed for redeveloped projects Distance between 2 adjacent buildings: the H/3 regulation is relaxed for the redevelopment schemes clause 33(7) in DCR, only6 mts minimum distance needs to be provided.

Case study: Girgaon, Mumbai

Girgaon, once characterized by coconut plantations and dense forests of plantain, underwent significant development in the mid-nineteenth century, evolving into a bustling hub for migrants relocating to Mumbai from various parts of the country. Today, it hosts a diverse array of communities, including Marathi, Gujarati, Konkani, and East Indians, with adherents of Christianity, Hinduism, Parsi, and Islam each having their own places of worship. Girgaon serves as the gateway to Bombay, pulsating with the city's essence. It was the residential area of the city's original inhabitants, while the English resided in apartments in Fort. In Girgaon, the mosaic of Bombay's communities is evident, with Khotachi representing a Christian enclave, Kalbadevi predominantly Gujarati, and Nikadwari and Kandewadi predominantly Maharashtrian, alongside Fanaswadi. While remnants of the early immigrant culture endure, signs of decay are also apparent.

The culture of these wadis has withstood the effects of time but the buildings & chawls housing its residents has become derelict & needs to be repaired. Due to the effect of development control regulation, the owners are unable to increase rents (Rent Control Act) to maintain the premises and hence the Chawls have been unkempt or in ruins. The authorities have floated the redevelopment scheme of cessed buildings (built before 1945) to counter the problem of derelict structures. Many chawls have undergone this redevelopment from the introduction of the scheme in 1991. Today Girgaon has become a jungle of tall buildings with inadequate light & ventilation due to the dense character of the original development. Many redeveloped structures have a small plot facing narrow streets. The area is situated in the heart of the city thus land value is exorbitant and redeveloped buildings are mainly residential in nature, due to the close proximity to the main market areas of Mumbai, lot of businessmen reside in these areas. The current changing urban fabric is dense & thus could be the cause of urban heat island. The comparison of the change in the urban fabric will be the method to prove that development control regulations can play an important role in the mitigation of urban heat island effects. The case study is an example of the effects of the development control regulations on the built fabric of the city causing heat gain to generate urban heat island effects

Parameters of the analysis

The parameters to study will encompass the following; urban form generation, streetsections, building materials, green cover, sky factor etc.

Urban form: The development control regulations are created to ensure fundamental byelaws are adhered to in the development of urban built environment. The urban form is a direct generation of the development control regulations in the region, in this case, the redevelopment scheme regulations for cessed buildings. The above paragraphs shows that for redevelopment schemes some relaxation of important building codes has been done thus resulting in dense & claustrophobic structures leading to heat gain in the areas.

The street section shows the ratio of the building to the street to ensure adequate light & ventilation

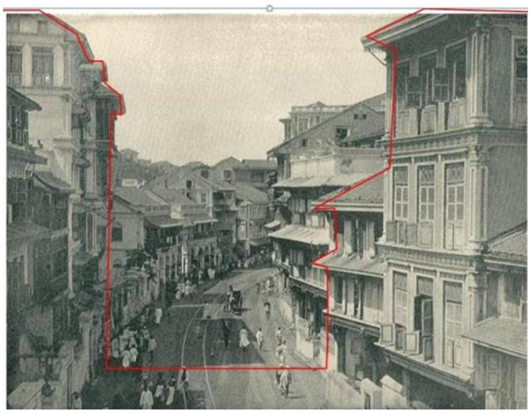

Figure 1: Street of Kalbadevi showing chawls Reference: ttps://www.mumbai77.com/city/4364/information-about/bombay-to-mumbai/

The street section shows the change scale of the ratio of the building to street in the same locality giving rise to heat entrapment due to lack of ventilation

Figure 2: Redevelopment project in Girgaon Reference:https://www.99acres.com/atlas-royal-girgaon-south-mumbai-npxid-r243121

Building materials: The chawls were built in load bearing or framed construction with sloping mangalore tiled roofs in the earlier days. The redeveloped buildings are high rise RCC buildings. The RCC roof causes heat gain compared to the Mangalore tiled roofs giving rise to ambient temperatures.

Green cover: The forms of the chawls were generally linear with a central courtyard which acted as social space for the communities. These had some trees and backyard gardens adding to the green spaces in the densely populated neighbourhood.

Sky Factor: The visibility of the sky is considered as an important part of liveable spaces, this has become a major setback in the new urban form shaping the region.

Built fabric: The change in the footprint of the built space on the same plot of land has caused further densification of the built fabric. The earlier chawls had a height to width ratio of 1:2 or 1:3 which created appropriate open space between two chawls such that basic requirements of residents such a light & ventilation was not compromised. The new redeveloped structures are built on the same plot of land to accommodate approximately double the built area causing a very linear structure. This has created less than adequate spaces between two buildings leading to lack of light, ventilation adequate green cover etc.

Figure 3: Google earth pro image of 2009 showing Girgaon
Reference: Google earth Pro image 2008

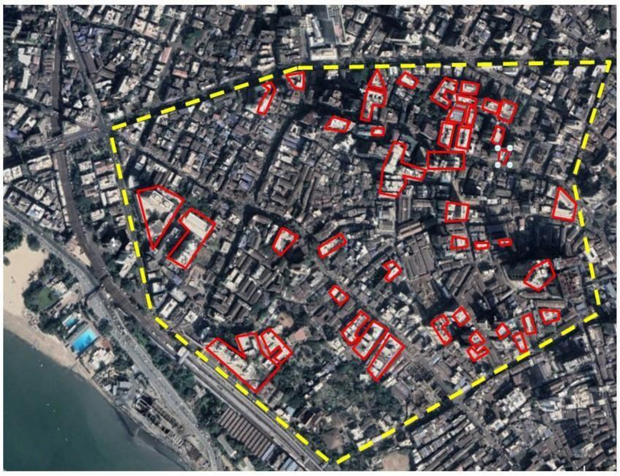

Figure 4: Google earth pro image 2023 showing Girgaon
Reference: Google earth Pro image @ 2024 Airbus, image @ 2024 Maxar technologies

The comparison between the 2 images shows the increase in the redevelopment projects over the last decade, the change shows how gradually all structures are becoming high rise buildings.

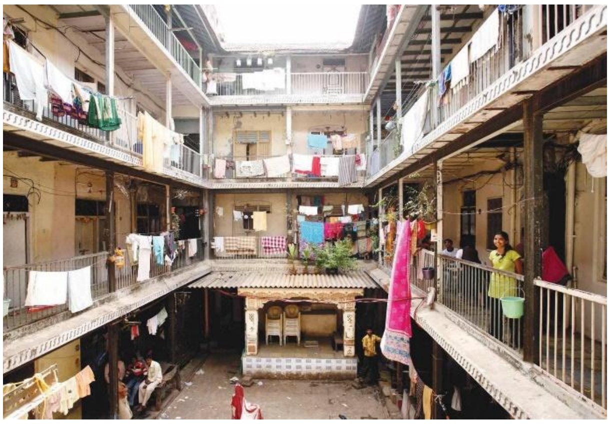

Figure 5: Chawl to show the building maetrials prevalent at the time
Reference:
https://www.magzter.com/stories/Lifestyle/Mans-World/Celebrating-Mumbais-Chawls

Figure 6: Redevelopment projects showing the materials used today
Reference: https://questionofcities.org/how-redevelopment-ruined-mumbais-housing-and-marred-the-landscape/

The two photos above show the shift in the material usage from chawls to the new building in Girgaon.

Figure 7: Dattatraya chawl showing the central open space

Reference: https://www.hindustantimes.com/mumbai-news/there-s-room-for-everyone-how-mumbai-s-chawlshave-been-housing-people-for-27-years/story ISMyYhgY2BQZzDNTcpG1sI.html

The space is not retained after redevelopment as the developer tries to maximize the area to build on the small plot of land.

The analysis states that the changes in development control guidelines play a pivotal role in ensuring sustainable built fabric. These regulations should be used as tools by the authorities to curb rapid urbanization causing deterioration of quality of life such as urban heat island effect which in turn create major concerns towards climate change.

Analysis and Inferences

Table 1: Analysis of the Parameters of the study

Parameters	Before Redevelopment Scheme	Current Condition Redevelopment Scheme Implemented (2023)
Urban Form	The chawls were built in load bearing construction thus restricting the height to 3-4 floors. the Chawls generally had central courtyards due to the linear planning thus creating green cover in the middle adequate to reduce heating.	With the current FSI of 2.5 -3 thus the total permissible built area has increased, thus give rise to linear tall structures with inadequate open spaces. the new floor plate does not have space to provide courtyards thus reducing green cover on the plot.
Built Fabric	The street to building ratio was 1:2, 1:3 maximum creating built fabric which was homogenous. The side open spaces were adequate considering the height of the chawls to ensure light & ventilation was accessible to all levels	The street to building ratio has changes drastically with the linear development to accommodate the permissible built areas. The side open spaces have been retained to prior dimension to ensure maximum plot is buildable thus creating concerns with adequate light & ventilation was accessible to all levels of the new structures.
Building Materials	Brick with timber & Mangalore tile roofs were the prevailing materials, these being better at providing thermal comfort within the structure were suitable to the environment.	RCC construction with glass facades being the trend of recent times, newer projects try to advertise these materials to attract customers. Though these materials are known to retain heat, further the denser built fabric also causes heat generated to be trapped they causing heat gain.

Green Cover	Central open spaces in the Chawls which provided social as well as green spaces in the plot.	The redeveloped project try to maximize the buildable plot area to accommodate the increased permissible built area, thus the green cover is compromised. The DCR does not specify mandatory provisions of the same in small plots less than 100 sq. mts. resulting in lot of plots developed with no green cover
Sky Factor	Due to the street to building height ratio and the ratio of side open spaces to height of buildings, all levels had access to visibility of sky thus, creating adequate pockets for winds to	Due to the changed street to building height ratio and the ratio of side open spaces to height of buildings, the lower levels generally are permanently in the shadow which causes claustrophobic ambience within the flats and lack of winds as the sky visibility in many times negligible

CONCLUSIONS

The study above shows through the case study

of one redevelopment scheme & its implementation how the neighbourhood has undergone transformation with respect to its landcover, built fabric & overall liveability in the last couple of decades. The regulation was introduced to overcome dilapidation of the existing chawls caused due to the rent control act & other regulations affecting the same. But the effect has been seen on the overall quality of life of the residents. There have been extensive redevelopment projects in the region over the years. They may have larger homes & modern amenities with such as lifts, air conditioners etc. within the same locality, but the quality of life has been compromised.

The urban heat island effect is an outcome of such changes to the built fabric which effect the neighbourhood gradually over several years. The development control regulations stipulated in the redevelopment scheme have not been made to overcome the compromise on the open space requirements, space between adjacent structures, building materials, green cover & sky factor, thus, causing heat gain which culminates into creation of an urban heat island effect in the region. The study tries to prove that the development control regulations can be a tool undertaken by the authorities to overcome causes such as urban heat islands which are the outcome of rapid urban development

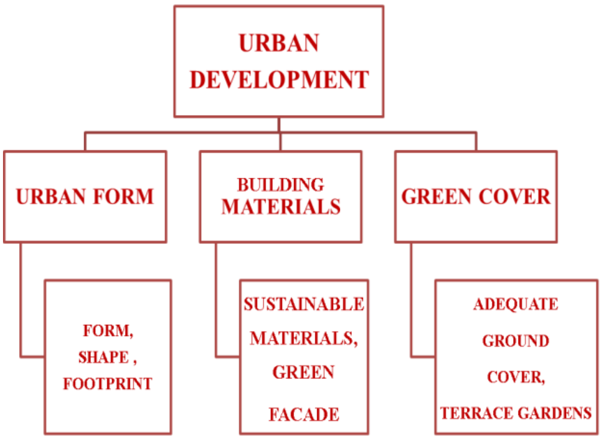

Figure 8: Chart to show the possible strategy

The above chart shows various parameters that can be tackled at building codes level to ensure liveable spaces in urban development.

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Evaluating The Impact of Double Skin Facades on Indoor Lighting Conditions in An Architectural College

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Abstract— Using a double-layer facade in architectural education studios is essential to improving human comfort. This creative design element fosters learning conditions by effectively integrating lighting elements and efficiently controlling heat gain. Its 8 AM to 5 PM operation guarantees ideal circumstances all day long, encouraging inhabitant creativity and productivity. The complete approach highlights a dedication to sustainability and user-centric design principles in addition to being an outstanding instance of design. The primary objective of this research project is to thoroughly study how Double Skin Facades (DSF) affect the indoor lighting conditions of an architectural building.

The use of DSF in architecture has become increasingly popular in modern building design because of its many benefits, including better thermal performance and lower energy usage. Specifically, DSF is made up of two transparent layers, such as glass, that are separated from one another by an air gap that serves as an insulating buffer zone. There aren't any DSF components in the architectural building in Pune, where the research is situated.

This location was selected with consideration for the research goal, which is to comprehend how various DSF materials impact the amount of natural light that enters interior spaces through simulation. The study isolates the variable of DSF materials to evaluate their effect on lighting conditions by maintaining a constant aperture size. A thorough simulated model of the DSF in the architectural building was developed to support this investigation. Understanding the architectural features and how they interact with natural light is made easier with the help of this model. To obtain quantitative data about the amount of natural light that enters the interior spaces at different times of the day and different periods, it conducted a thorough field data collection. The process of gathering data included determining and documenting the illumination levels in various settings. To make inferences about the lighting performance of various DSF material s, a thorough analysis of the gathered data was conducted. The study attempts to determine which kind of DSF is best suited for the site in terms of obtaining ideal indoor illumination by comparing the data collected during different times of the day and different periods

Keywords: Indoor Illumination; Building Design; Architectural College; Double Skin Façade; Single Skin Façade.

INTRODUCTION

In the constantly evolving field of modern architecture, the pursuit of well-lit, sustainable structures has taken center stage. The Double Skin Facade (DSF) is an inventive architectural feature that has attracted a lot of attention in this endeavour. With its two transparent layers— typically made of glass separated by an insulating air gap, DSF presents special possibilities for improving interior lighting. This study explores the effects of DSF with an emphasis on how it affects the amount and quality of natural light in an architectural building's interior spaces.

Indoor illumination is an important but frequently bypassed component of architectural design. Good lighting has a significant impact on building energy consumption and sustainability, as well as occupant comfort and productivity. In a time when an environmentally friendly design is crucial, creative ways to maximize natural light are needed. This study explores how double-skin facades (DSFs) are transforming the illumination of interiors in the current structures. DSF is becoming a more popular option for designers and architects due to the rising demand for sustainable architecture. Notably, DSF components were not originally incorporated into the research site, an architectural building, in Pune. Because of this deliberate choice, which keeps the aperture size constant, the investigation is placed in a controlled environment that enables us to focus exclusively on the variable of DSF materials and their impact on indoor lighting conditions. or double-skin facades is an architectural idea that has been developed over time. A DSF is primarily made up of two glass or other material layers separated by an air gap. The outermost layer acts as a barrier against outside influences. Since the air gap presents a special chance to control natural daylight, DSFs are an appropriate choice for interior illumination.

DSFs are excellent at optimizing the penetration of natural light. It can be achieved to optimize daylight inflow by adjusting the façade's orientation and design, which reduces the need for artificial lighting. Significantly, it has been demonstrated that adequate exposure to natural light improves occupant productivity, well-being, and health. DSFs can design spaces that improve building occupants' quality of life. Boundaries of what is practicable are being promoted by developments in emerging technologies and DSF designs. DSFs are being provided with automation and smart controls, which enable real-time modifications to optimize temperature and lighting. These developments create new opportunities for the effective use of DSFs in a wide range of building types.

Figure 1 : Ventilated façade in Medical Center Reference: https://www.archdaily.com/catalog/us/products/33031/ventilated-facade-in-medical-center-gres-aragon

Figure 2: Navodaya Educational Institution

Reference: https://wfmmedia.com/double-skin-facade-navodaya-educational-trust-educational-institution/

The simulations conducted in this study can be linked to virtual experiments. Instead of physically altering and constructing classrooms, which would be costly and time-consuming, they utilized computer simulations to test the impact of the double-skin facade. Simulations in architectural research allow for a controlled environment where variables can be adjusted and examined with precision. In this case, they isolated the effect of the double-skin facade on indoor lighting without any external factors interfering. Moreover, these simulations were conducted at various times throughout the day, covering different lighting scenarios. This approach is essential because natural lighting conditions change over a day due to the sun's movement. By examining the effects of the double-skin facade at various times, the study offers a comprehensive understanding of how this design impacts lighting conditions in a classroom under different scenarios.

The aim is to assess the impact of a double skin facade on interior lighting in a classroom at BNCA that faces west while maintaining the aperture size constant while considering the higher heat exposure that west-facing facades usually experience.

- To Assess the impact of a Double Skin Façade (DSF) on indoor lighting through simulations.
- To Investigate how types of DSF affect indoor illumination while keeping the aperture size constant.
- To analyze different DSF configurations to optimize indoor lighting in different seasons and active months of the academic year.

In the research paper, the focus was primarily on a specific classroom situated within the campus, in Pune. The choice of this setting held significance due to its contextual relevance. The research delved into the intricate domain of options within Double Skin Facades (DSF). This concentrated approach sought to comprehensively investigate how the selection of DSF influenced indoor lighting quality, all while maintaining a consistent aperture size. To accomplish this, simulation techniques were primarily employed to evaluate the impact on illumination within the selected classroom. The research was confined to a specific classroom setting, and despite acknowledging the effect of other elements, the scope of these elements was limited.

LITERATURE REVIEW

Whan (2023) investigated factors affecting indoor illumination control systems, particularly focusing on a system incorporating white light-emitting diode (WLED) matrices and tabletop controls. They considered sunlight variations, WLED matrix arrangement, iterative functions for optimizing illumination, and WLED optical spectra. The research revealed that non-symmetrical WLED tabletop matrices, optical spectrum choices, and changing sunlight intensity significantly impacted illuminance distribution. Additionally, the selection of iterative functions, WLED matrix size, error coefficient, and optical spectra affected energy savings and iteration steps. This study offers valuable insights for optimizing indoor illumination control systems, with potential applications in manufacturing and intelligent office buildings (Whan,2023).

Maliek (2019) presents an innovative indoor solar illumination system, combining a tracking primary reflector, selective secondary reflector, visible light guide, and scattering glass tube fixture for efficiency. Simulations conducted in a Baghdad library hall during the summer and winter solstices at 8:00 AM and 12:00 PM aimed to achieve suitable reading light levels. Results showed that the design met the required illuminance for office work, favoring an aluminium-coated primary reflector, which provided 538Lux for reading compared to 589Lux with a silver-coated reflector. This research contributes to the field of indoor solar illumination, improving reading and office lighting. (Maliek, 2019).

Twentieth-century architecture faced the challenge of energy efficiency and environmental concerns. The design of a building's exterior is crucial for energy various times throughout the day, covering different lighting scenarios. This approach is essential because natural lighting conditions change over a day due to the sun's movement. By examining the effects of the double-skin facade at various times, the study offers a comprehensive understanding of how this design impacts lighting conditions in a classroom under different scenarios.

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In the construction field, achieving efficient building design is not unbreakable. People working in the construction industry, including architects, strive to create environmentally friendly building designs because of the various environmental issues that are related to building design. The design of buildings, people, and the environment could all benefit from Double Skin Facade (DSF) in several ways. The definitions of the DSF design and functions are defined using a variety of criteria. (Zin, Jamil, Ibrahim, Tazilan,2020). The performance of double skin facades in hot, dry zones during the day is the subject of research. Models facing south were subjected to the Protocol in cloudy sky conditions. According to simulation results, a double-skin facade can save more energy and achieve higher lighting performance than a single-skin facade. (Ghonimi,2017)

The importance of daylighting in energy-efficient building design was investigated using Bank Mega, a coastal tall building in Makassar, Indonesia, as a case study. Jamala B & Hamzah (2023) used a quantitative approach to examine the performance of sunlight in office spaces with northeast and southwest orientations. While daylight distribution varied with building orientation, the massive glass facade model with no sun shading had the highest light distribution value but could have caused glare and excessive brightness. In terms of overall daylight distribution, the vertical facade model came in second, with some areas near windows exceeding standard illuminance levels. These findings emphasized the significance of building orientation in terms of daylighting. (Jamala B & Hamzah ,2023).

Anime, Soumaya, and Guedoh (2021) addressed the challenge of optimizing thermal conditions in building facades while minimizing energy consumption, which was especially important given the prevailing economic and climatic conditions. The focus of the study was the double skin facade (DSF) in a desert climate, specifically in Biskra. The research evaluated the impact of the DSF on energy efficiency through a combination of numerical simulations and an experimental approach using a scale model. The findings indicated that the DSF proved to be an effective and durable solution, notably enhancing thermal and energy performance, especially during hot summers, while also contributing to environmental preservation. This study underscored the significance of innovative facade design in improving building sustainability and enhancing user comfort. (Khadraoui, Soumaya, and Guedoh,2021).

METHODOLOGY

In architectural design, the orientation of a building, particularly its facade, plays a crucial role in determining the penetration of natural light into its interior spaces. The study compares two distinct 3D models, both oriented with west-facing facades, to evaluate the effect of this design feature on the amount of natural light within a classroom. The first 3D model serves as a benchmark, representing a traditional classroom with a single-skin facade. This model provides a reference point for understanding the standard conditions of natural lighting in a classroom without any specialized architectural features. In contrast, the second model features the innovative double-skin facade design, which incorporates two walls with a gap between them. This double-skin facade design is known for its potential to improve energy efficiency and indoor comfort by offering enhanced thermal and lighting properties. To conduct their investigations of Rhino, a specialized computer program often used in architectural design and analysis. This software enables the creation of detailed 3D models and simulations, making it an ideal tool for studying the effects of architectural changes on interior lighting conditions. Ladybug, a Rhino plug-in was used to create accurate and realistic representations of the classroom models, ensuring that the study's findings would be applicable in real-world architectural settings.

The primary goal of this investigation is to quantitatively analyze how the innovative double-skin facade influences the amount of natural light within the classroom. They likely measured and compared parameters such as illuminance levels, glare, and uniformity of lighting between the two models. The double-skin facade's design could affect the amount of direct sunlight entering the classroom, how that light is diffused within the space, and whether it reduces the need for artificial lighting, which is essential in creating a sustainable and comfortable educational environment.

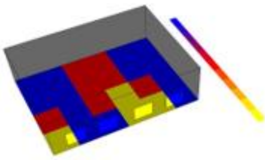
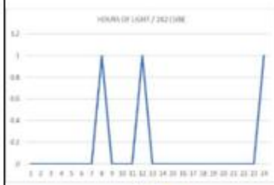
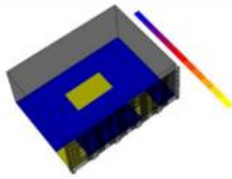
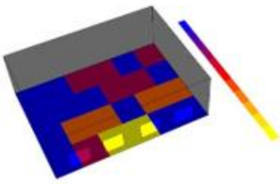
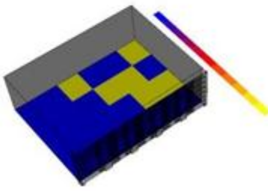
The study employed RHINO with the Ladybug plugin, specialized software that offers precise control over sunlight based on specific time and date parameters. The research utilized a 3D model of a classroom of an architectural building situated in Pune, with west-facing facades. These intricately designed models allowed for a visual representation of how natural light levels change throughout the day, delivering valuable insights into lighting conditions across various times and dates.

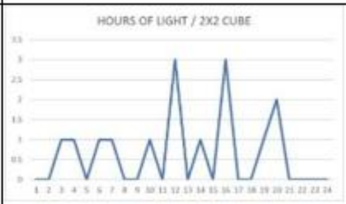
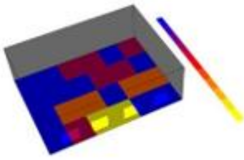
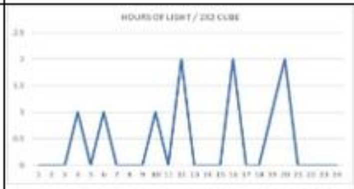
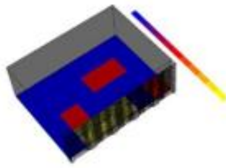
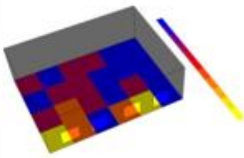
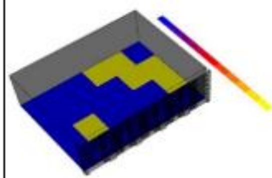
The application of RHINO-Ladybug for illuminance calculations within the classroom generated quantitative data regarding both the quality and quantity of natural light. This data served multiple purposes, including the optimization of window placement, compliance with design standards, and the evaluation of energy efficiency for creating well-lit and sustainable educational spaces.

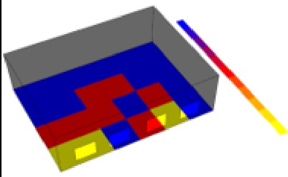
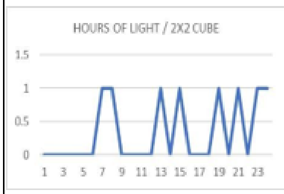
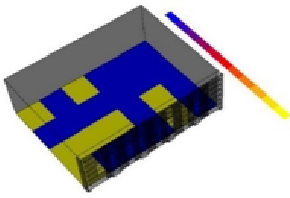
Data analysis

The research collected data through simulation in Rhino Ladybird, comparing two distinct scenarios: one with a single facade and the other with a double-skin facade. Using these simulations, detailed monthly and annual data was thoroughly gathered, providing a comprehensive understanding of how different facade designs influenced the building's energy performance. This comparative analysis provided valuable insights into the impact of facade design on the daylighting factor of a building, thereby advancing the development of more sustainable architectural solutions.

Table 1: Monthly comparison between single skin façade and double skin façade

Time Period	Single skin facade	Double skin facade
Summers (15th March – 15th April)	  Maximum hours of light near the opening- 14 hours	  Maximum hours of light near the opening – 1 hour
Analysis- In the regions bordering the openings of a single-skin facade, there was a maximum of 14 hours of monthly light, and the central area received a minimum of only 20 minutes of illumination.		
Summers (15th May – 15th June)	  Maximum hours of light near the opening - 15 hours	  Maximum hours of light near the opening – 1 hour
Analysis- In the areas adjoining the apertures of a single skin facade, a peak of 15 hours of monthly light exposure was observed during the summer season. In contrast, double skin facades consistently maintained		

Time Period	Single skin facade	Double skin facade
Monsoon (15th July – 15th August)	  Maximum hours of light near the opening – 3 hours	  Maximum hours of light near the opening – 2 hours
Monsoon (15th August – 15th September)	  Maximum hours of light near the opening – 3 hours	  Maximum hours of light near the opening – 1 hour
Analysis- Near the entrances of a single-skin facade, there was a monthly peak of 3 hours of light exposure, particularly during the monsoon season. On the other hand, double-skin facades consistently provided a stable 2-hour monthly light exposure.		

Winters (15th November- 15th December)	 	 
Analysis- In the areas close to the entrances of a single-skin facade, there was a monthly peak of 3 hours of light exposure, especially during the monsoon season. In contrast, double-skin facades consistently offered a consistent 1-hour monthly light exposure.		
Analysis- Near the entrances of a single-skin facade, there used to be a monthly peak of 3 hours of light exposure, especially during the winter season. In contrast, double-skin facades consistently used to offer a steady 1-hour monthly light exposure.		

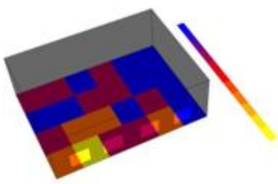
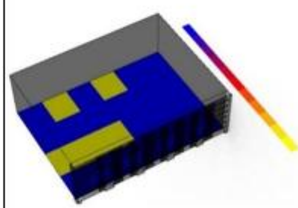
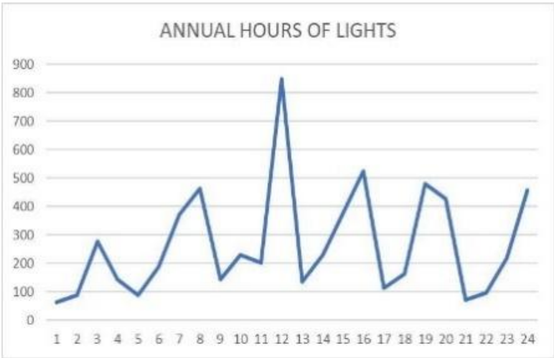
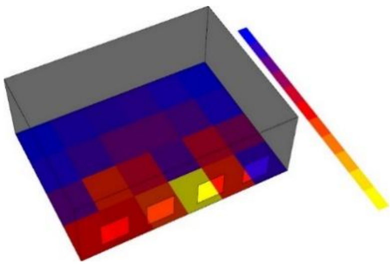
Winters (15th December – 15th January)	  Maximum hours of light near the opening – 3 hours	  Maximum hours of light near the opening – 1 hours

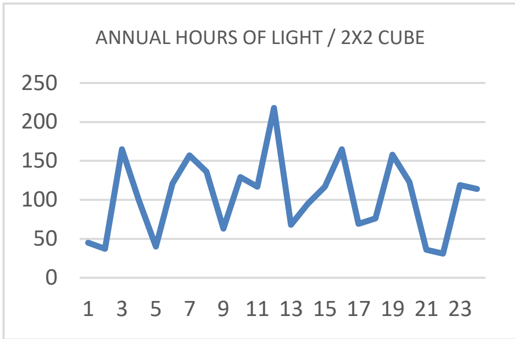
Table 2: Annual lighting comparison between Single skin façade and Double skin façade-

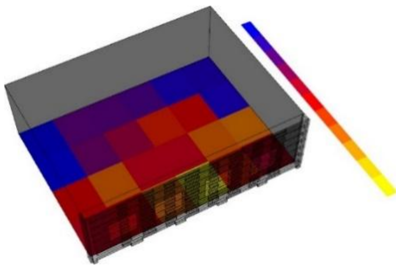
<table>
<tr><th>Single skin facade</th><th>Double skin facade</th></tr>
<tr><td>





</td><td>





</td></tr>
</table>

Annual light conclusion

There was a noticeable difference in the amount and distribution of natural light between single-skin facades and double-skin facades. Single-skin facades used to receive the most natural light, which was about 850 hours per year. This light, however, used to be concentrated near the windows, with areas further away from the windows receiving minimal illumination. Conversely, despite receiving less light around 250 hours per year, double-skin facades are used to demonstrate a more even distribution of light throughout the entire interior space. Even those areas far from the windows used to get a decent amount of natural light. This even distribution of light throughout space used to be a significant advantage. The advantage of even light distribution in double-skin facades was that it resulted in a more balanced and consistent lighting space inside the building. This is used not only to improve overall lighting quality but also to reduce the necessity of artificial lighting, particularly in areas away from windows. As a result, there was a significant decrease in energy consumption associated with artificial lighting. Earlier comparisons of single and double-skin facades demonstrated that, while the latter received less total light, it made much better use of the light it did receive, contributing to energy efficiency and sustainability in building design.

Through this research, architects and researchers gained a deeper understanding of the critical role that facade design plays in sustainable architecture. The data revealed that double-skin facades, with their additional insulation and layers, can significantly reduce energy consumption, particularly in heating, cooling, and lighting. This information was vital for making informed architectural decisions and promoting the adoption of eco-friendly designs in the construction industry. Overall, the findings from this study have the potential to reshape the way buildings are designed, making them more energy-efficient and environmentally friendly, and ultimately reducing their carbon footprint.

CONCLUSION

In conclusion, there was a noticeable variation in the quantity and distribution of natural light when single-skin and double-skin facades were compared. In contrast to double-skin facades, which displayed a more even distribution of light throughout the interior space, single-skin facades received more natural light overall, primarily concentrated near the windows. Double skin facades delivered several benefits, including improved lighting, a reduction in the need for artificial lighting, and lower energy consumption, since architectural colleges required a good amount of light due to the precision of their work. Overall, the results indicated that double-skin facades are a more sustainable and energy-efficient option for building design, supporting environmentally friendly architectural Institutes.

Acknowledgment

Our sincere thanks extend to Prof. Dr. Sujata Karve and Assoc. Prof. Deva Prasad from Dr. Bhanuben Nanavati College of Architecture, Pune for their significant contributions to this study. The advice and positive feedback provided by Prof. Dr. Sujata Karve have greatly improved the quality of the research. The conceptual framework and technique have been enhanced by Prof. Deva Prasad's assistance. In addition, the research activity has gained depth from Ar. Rachana Patil's determined contributions. Their combined aid has been invaluable, and we sincerely appreciate all that they have done for us throughout this research.

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Acoustical Materials in Auditoriums: Analyzing Installation Techniques and Assessing VOC Emissions

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Abstract— Gathering spaces have played a significant role in our society since ancient times, serving as venues for announcements, functions, and various activities. These spaces, designed specifically for social gatherings, include auditoriums, multipurpose halls, open-air theatres, as well as religious places such as temples, mosques, and churches. Throughout history, the creation of these spaces reflects the innate social nature of human beings and the importance of communal interaction in various aspects of life. Auditoriums, which are expansive spaces used for stage performances, speeches, and public assemblies, share a common set of basic acoustic criteria. These criteria include maintaining low ambient noise levels from both external and internal sources, eliminating echoes and flutter, and ensuring appropriate reverberation time. To meet these criteria, the use of suitable acoustical materials for the floor, ceiling, and walls becomes imperative. Contemporary acoustical materials, as well as adhesives for panel and carpet installation, and paints used in auditoriums, emit Volatile Organic Compounds (VOCs). The presence of high VOC content in these materials can lead to a decrease in occupant productivity, respiratory problems, and various illnesses. Therefore, it is crucial to investigate the VOC emissions of different contemporary materials and recommend appropriate choices for the floor, ceiling, and walls of the auditorium. This paper delves into the study and analysis of acoustical materials, VOC emissions, absorption coefficients for different frequencies, and installation techniques. By examining various types of materials and installation methods, the paper aims to provide insights into selecting the most suitable options for the floor, wall, and ceiling of a multipurpose hall.

Keywords: VOC emission, Absorption coefficient, Acoustical materials, installation techniques.

INTRODUCTION

In contemporary architectural settings, effective acoustical design is imperative, particularly in spaces such as auditoriums that host drama, performances, and musical programs. Acoustic comfort is a crucial aspect of such buildings. The absorption coefficient, denoting the proportion of incident sound energy absorbed by a surface, plays a pivotal role in achieving optimal acoustics.

According to the law of conservation of energy, energy cannot be created or destroyed but can be transformed from one form to another. In the context of acoustics, absorption serves as a mechanism to convert sound energy into heat energy. While it's possible to reduce sound levels within rooms, controlling sound transmission between rooms presents a distinct challenge.

When sound energy encounters a material, a portion of that energy is absorbed by the material. The quantification of this absorbed energy is known as the absorption coefficient. The absorption coefficient is the ratio of absorbed energy to the incident sound energy. Conversely, the reflection coefficient represents the ratio of reflected sound energy to the incident sound energy.

A material with an absorption coefficient of zero reflects all incident sound energy, while a material with a coefficient of one absorbs all incoming sound energy. In practice, no material exhibits complete reflection or absorption; thus, an absorption coefficient of one represents a theoretical limit. All materials inherently absorb some amount of sound energy.

Various forms of sound absorptive materials find applications in diverse conditions. These materials serving to enhance acoustical conditions without exist in different structures, compromising the overall design. By understanding and manipulating absorption coefficients, architects and designers can create environments that strike a balance between acoustic functionality and aesthetic appeal.

The sound absorption coefficient and Noise Reduction Coefficient (NRC) values vary among different materials, influencing the acoustical environment of a space. The ideal reverberation time (RT) for an auditorium depends on its intended use. An auditorium's RT should be sufficiently long, ideally ranging from 1.5 to 2.5 seconds. Notably, this duration should be longer for low-frequency sounds and shorter for high-frequency sounds. (Shiney A, March 2015)

Indoor air quality (IAQ) directly impacts the comfort and well-being of building occupants. Volatile Organic Compounds (VOCs) are organic chemical compounds with significant vapor pressures, posing potential harm to human health and the environment. Materials with high VOC content can lead to health issues and affect occupant productivity. VOCs are substances containing carbon that evaporate at room temperature (Table 1).

Table 1: Some Volatile Organic Compounds And their Harmful side effect (Evuti, 2013)

	VOCs	HARMFUL EFFECTS
1	Benzene	Causes cancer
2	Toluene	Sore head and sensation of spinning around.
3	Xylene	Respiratory tract and eye touchiness, downer effect, sadness and death
4	Chloroform	Disturb central nervous system producing sensation of spinning around, depression, kidney and liver damages, skin disease
5	Ethylene, Styrene	ozone layer depletion of
6	Acetaldehyde, acetone	Breathing and eye annoyance
7	Phenol	Strong odor and poisonousness
8	Epoxides	Poisonous, Causes cancer
9	Ethers	Creating peroxides, upsetting the procreative system
10	Vinyl chloride, Freon	Ozone layer depletion , greenhouse result, cancer-causing, poisonous, climate changes
11	Nitrogen holding compounds	foul odor, cancer-causing (disturbing urinary bladder)

To ensure a good acoustical environment, it is crucial to examine the sound absorption coefficient and NRC values of various materials. Additionally, evaluating the VOC contents of these materials using Material Safety Data Sheets (MSDS) or Product Data Sheets, provided by suppliers or manufacturers, helps estimate potential air emissions. This comprehensive analysis guides the selection of suitable materials for the floor, wall, and ceiling of the auditorium, balancing both acoustical performance and indoor air quality.

METHODOLOGY

- Conduct a case study of auditoriums to analyze the acoustical materials utilized.
- Compile absorption coefficient and Noise Reduction Values for various contemporary materials into a comprehensive list.
- Gather data on VOC content and installation practices of contemporary acoustical materials from manufacturers through Material Safety Data Sheets (MSDS), Product Data Sheets, and brochures.
- Derive analytical conclusions based on data collected through the case study method, market survey, and collection of VOC emission and installation data.

Live case study

Case study of management education society (MES)

Balshikshan School Campus Auditorium, Kotharud, Pune

Situated in Kothrud, Pune, the Management Education Society Auditorium holds significant importance. Over the years, it has evolved into a cultural hub for music, concerts, and drama. The venue has hosted various events, including gatherings, discussions, cultural meets, and book release functions. The acoustical materials used in the Balshikshan School Campus Auditorium analyzed for their sound absorption coefficient and NRC values, as well as their VOC contents and installation techniques. The analysis of acoustical materials in the Balshikshan School Campus Auditorium will provide valuable insights into their impact on the acoustical environment and indoor air quality of the auditorium.

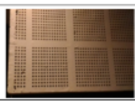
Table-2 List of Adhesives and Materials used

Material	Area	Size mm	Adhesive, sealants, Polish	Thickness mm	Images
Wood wool board with glass wool	wall	600 x 600	-	12	
Processed rubber wood	wall	2400 x 1200	maelamine polish	12	
Asona spray plaster on gypsum board	Wall	600 x 600	-	12	
carpet	Floor	-	Rubber based Fevicol SR-505	-	

Case study of Keshavrao Bhosale Nattyagruh At Kolhapur

Maharashtra's oldest auditorium, recently restored to its former glory by the Kolhapur Municipal Corporation, stands as a historic venue. This significant restoration has rejuvenated the iconic space, making it a testament to the preservation efforts by the municipal corporation. (Table 3) The case study of Keshavrao Bhosale Nattyagruh at Kolhapur will analyze the acoustical materials used in the venue, including the floor, wall, and ceiling materials. The analysis will focus on the sound absorption coefficient, NRC values, VOC content, and installation techniques of these materials. The findings from this case study will offer valuable insights into the acoustics and indoor air quality of the Keshavrao Bhosale Nattyagruh Auditorium.

Table-3 List of Adhesives and Materials used

Material	Area	Adhesive, sealants, Polish	Size mm	Thickness mm	Images
Opta ceiling tiles	Ceiling	-	600 x 600	12	
Wood Work Ceiling Panels with maelamine polish	Ceiling	-	601 x 600	13	
Wood Work Wall Panels with maelamine polish	wall		602 x 600	14	
			2440X128	16	
Gyptone series fultone 50mm glass wool behind it	Wall		600 x 600	12.5	
Vinyl Floor	Floor	Arobond 44	-	-	

Comparative analysis

Conduct a case study for a comparative analysis of flooring material (Table-4), adhesives (Table-5), and material used (Table-6)

Table-4 Comparative Analysis of Flooring materials

Case study	Case study 1	Case study 2
Material	**Carpet**	**Vinyl flooring**
area (Floor, ceiling, Wall)	Floor	Floor
VOC	Low or 0	≤ 10 µg/m3 (after 28 days)
Application techniques (sealants, adhesive etc.)	S-515, S-525, S-700, or S-751,Rubber based Fevicol SR 506	S-515, S-525, S-700, or S-750
NCR (Noise reduction coefficient)	0.59	0.05
Size	Roll	Roll

Table-5 Adhesives used for Floor and Walls

Specifications	Application area	Type	VOC Content
S-525 Clear Thin Spread BioBased Tile Adhesive	Vinyl floor	Water-based/latex	**16.2 g/L (SCAQMD 1168)**
S-515 Clear Thin Spread Tile Adhesive	Carpet, Vinyl floor	Water-based/latex	**49 g/L (SCAQMD 1168)**
S-700 Thin Spread Floor Tile Adhesive	Carpet, Vinyl floor	Water-based/asphalt-rubber	**Zero g/L (SCAQMD 1168)**
S-750 Thin Spread Floor Tile Adhesive	Commercial Vinyl Primer for wood and concrete with self-adhering tile	Water-based/rubber resin	**5.9 g/L (SCAQMD 1168)**
S-288 Premium Vinyl Sheet Flooring Adhesive	• Fiberglass-Reinforced Sheet Flooring • Commercial Luxury Vinyl Tile Flooring	Water-based/rubber resin	**14 g/L (SCAQMD 1168)**
S-240 High Performance Epoxy Flooring Adhesive	• Vinyl Composition Tile	Two-part epoxy	**10g/L (SCAQMD 1168)**
Fevicol SR 505	Carpet, Vinyl floor, Glass Wool, Rock Wool	rubber resin	**5 gms / litre**
Arobond 44	Vinyl floor	water based	**Zero g/L (SCAQMD 1168)**

Table 6 Comparative Analysis

		Case study 1		Case study 2					
Material		Wood wool board	Asona acoustical plaster	Optra ceiling tiles	WoodWorks Ceiling panels	WoodWorks Wall panels	Gyptone perforated pannels		
area (Floor, ceiling, Wall)		Wall / ceiling	Wall	ceiling	ceiling	Wall	Wall/ Ceiling		
VOC		24 µg/m³ (7 days)	-	0%	low	low	0%		
Plenum (Air Cavity)		-	-	-	-	-	65mm	65mm	45mm
Application techniques (sealants, adhesive etc.)		Framing, bolting	Spray gun / manually sprayed by troweling	Impaling clips (Adhesives), Z-Clips wall mount, Rotofast snap-on Anchor	Framing, bolting	Framing, bolting	Framing		
Material use for application (sealants, adhesive etc.)		-	Spray gun / manually sprayed by troweling	-	-	-	-	-	-
Insulation		50 mm Glass wool	-	-	-	-	without insulation	50mm glass wool 14 kg/m3	45 mm of underlaying mineral wool
Absorption coefficient For Frequency	125	0.27	0.1	0.64	0.56	0.35	0.2	0.4	0.35
	250	0.56	0.35	1	0.64	0.76	0.35	0.65	0.65
	500	1	0.8	0.96	0.43	0.48	0.55	0.8	0.85
	1000	0.93	0.95	0.8	0.19	0.5	0.75	0.7	0.85
	2000	1	1	0.92	0.1	0.5	0.6	0.65	0.75
	4000	0.81	1	1	0.04	0.57	0.4	0.55	0.75
NCR (Noise reduction coefficient)		0.87	0.78	0.92	0.34	0.56	0.56	0.70	0.78
Analysis		it has low but some amount of VOC content. Its absorption coefficient is less material is more reflective than absorptive. It can be installed by framing and bolting.	it has low but some amount of VOC content. They are applied by spray gun or manually sprayed by troweling by a skilled person. As thickness increases absorptivity increases particularly at low frequencies. it is absorptive.	it has 0% VOC content aesthetically it is attractive. Its absorption coefficient is more than 0.5 this material is absorptive. It can be installed by framing and bolting.	it has low but some amount of VOC content aesthetically it is attractive. Its absorption coefficient is less than 0.7 this material is more reflective than absorptive. It can be installed by framing and bolting.		It has 0% VOC content aesthetically it is good. NRC typically ranges from 0 (total reflection) to 1.00 (total absorption). For perforated products, the NRC is dependent on the amount of open surface area, the type of acoustic fabric, the use of additional insulation material and the depth of the air cavity (plenum) behind the lining. It can be installed by framing and bolting.		

Various Mounting System

Impaling Clips

Begin by determining the mounting location for the panel and marking the outer edges on all sides. Utilize appropriate fasteners to affix clips to the wall, ensuring they are positioned at least 6 inches from the outer edge. Apply an ample amount of adhesive to the panel's back, align it with the marked position on the wall, and press it onto the clips to secure them into the fiberglass core. Verify that the panels are straight and precisely positioned. These clips serve to hold the panel in place while the adhesive sets.

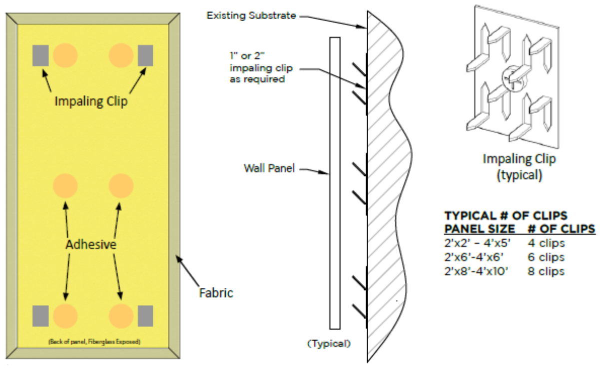
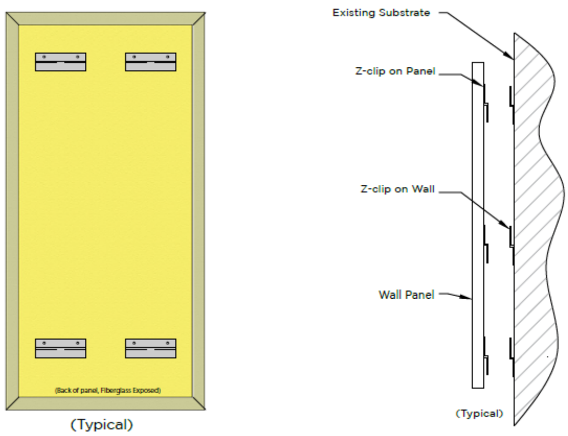


Figure. 1: (Source: acoustical solutions broacher)

Z-Clips Wall Mount

The fasteners, comprised of two parts, are employed to mount panels by attaching to the back. The order includes these wall clips. Determine the panel locations, aligning the same mounting points on the panel with the clips on the back. Mark reference lines on the wall to verify the panel's position and level. Install z-clips onto the wall using appropriate fasteners. Secure the panel z-clips onto the wall z-clips, following the same procedure for all panels.



Rotofast Snap-On Anchor

Figure. 2: (Source: acoustical solutions broacher)

Ensure your acoustical panel order includes the appropriate quantity of Rotofast Snap-On Anchors and necessary accessories for the project. The anchors come pre-installed on the back of the panel, and it is advisable to use an adequate number of marking plugs to guarantee sufficiency for the largest panel.

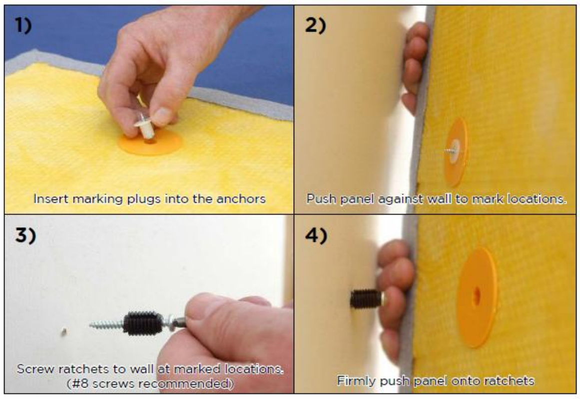


Figure. 3: (Source: acoustical solutions broacher)

CONCLUSION

In the case of auditoriums, the significance of low or zero VOC emission materials extends beyond their selection to encompass installation techniques, adhesives, paints, insulations, and their respective VOC emissions. Take, for instance, Alphasorb Acoustic Panels, acknowledged for their low VOC content and offering various mounting systems such as Impaling Clips, Z-Clips Wall Mount, and Rotofast Snap-On Anchor. (Ref: Figure) Notably, the Impaling Clips mounting system involves the use of adhesive, emitting a certain level of VOCs. To mitigate VOC emissions, opt for Z-Clips Wall Mount or Rotofast Snap-On Anchor Mounting Systems.

Given the substantial quantity of acoustical materials used in auditoriums, even when utilizing low VOC materials, the overall VOC emissions may be significant. To address this, consider employing zero VOC materials, eliminate the use of adhesives and paints emitting VOCs, and carefully choose appropriate installation techniques.

Acoustical materials for Ceiling

Optra ceiling tiles boast a 0% VOC content, making them visually appealing. With an absorption coefficient exceeding 0.5, these tiles are highly absorptive. Installation is facilitated through framing and bolting.

Wood Works Ceiling panels, while aesthetically pleasing, contain a low level of VOCs. However, their absorption coefficient falls below 0.7, indicating a more reflective than absorptive nature. These panels can be easily installed using framing and bolting methods.

Acoustical materials for wall

Wood Works Wall panels exhibit an appealing aesthetic despite containing a low but noticeable level of VOCs. With an absorption coefficient below 0.7, this material leans more towards reflectivity than absorption. Installation is achieved through framing and bolting methods.

Asona acoustical plaster, with its attractive aesthetic and low VOC content, can be applied either by a spray gun or manually by a skilled person using a trowel. As thickness increases, particularly at low frequencies, absorptivity also increases. Asona acoustical plaster is characterized by its absorptive properties.

Acoustical materials for Ceiling/Wall

Gyptone perforated panels boast a 0% VOC content and are visually appealing. The Noise Reduction Coefficient (NRC) of these panels varies from zero (reflecting all incident sound energy) to one (absorbing all incident sound energy). The NRC is influenced by factors such as extra insulation, air cavity, the type of fabric used, and the exposed surface area. Installation is facilitated through framing and bolting.

Wood wool boards emit 24 μg/m^3 (7 days) of VOCs. These boards are mounted on a wooden frame with glass wool insulation, and the installation involves bolting the panels to the wooden frame, with no use of adhesive or paint.

Acoustical materials for Flooring

Vinyl flooring exhibits VOC emissions of ≤10 μg/m3 (after 28 days) and possesses a low absorption coefficient. Installation involves the use of adhesives such as S-515, S-525, S-700, or S-750.

Carpete, with either 0 or low VOC emissions, surpasses vinyl flooring in absorptive properties. The installation process for carpets also utilizes adhesives.

When selecting adhesives for flooring, it is advisable to opt for those with low or zero VOC content. Choose 0 VOC adhesives like Arobond 44 or S-700 to minimize environmental impact.

Acknowledgements

The authors would like to acknowledge the Balshikshan School Campus and the Keshavrao Bhosale Nattyagruh Auditorium for allowing us access to their facilities and providing information for our analysis. The information gathered from these case studies will contribute to a better understanding of the acoustical properties and indoor air quality in auditoriums.

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Accessing the impact of traditional CBDs on Liveability: A case of Tiruchirapalli city

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Abstract— Central business districts (CBDs) are the vibrant cores of the cities. In India, CBDs have a unique history, evolving organically since ancient times. If these are planned well, they become crucial to the functioning of urban areas, offering a dense and compact mix of commercial, public, residential, institutional, and religious activities. However, older settlements often struggle with high population density and pollution as they were not designed for such dense concentrated activity. The question now arises to understand how these historic CBDs effectively support a city's function and promote livability within their boundary. The context chosen for the study is Tiruchirapalli, Tamil Nadu, a prominent hub of tourism, commerce, education, and industry. Its' CBD, called the Rockfort area, is where the city's growth started. It contains a religious and heritage precinct as well that attracts tourists from around the world. By reviewing the literature and conducting questionnaire surveys for people's perceptions of liveability, comfort, and convenience, various parameters can be found. The collected data can then be analyzed using statistical methods (SPSS). Based on the results, the possibilities for optimization can be explored to create thriving and sustainable urban environments.

Keywords: central business district; livability; urbanization; city function; urban fabric.

INTRODUCTION

Central Business Districts (CBD) serve as the economic hubs, offering employment opportunities. The concept of livability encompasses factors, such as morphological dimension, economic prosperity, equitable access, cultural connections, socializing potential, and quality of recreation facilities. In addition to this in any historic city, the CBD not only serves as an economic center but also holds religious and cultural significance. This is very much true for the case of the city of Tiruchirapalli, Tamil Nadu. With rapid urbanization and increasing city demands, the CBD area known as The Rock Fort became denser, and became an inalterable space. It faced numerous limits and obstacles over the past few decades due to an absence of space for facilities (parking, green space), excessive rental rates, spatial inconvenience, and extended travel hours for people living there. Urban Planning Policies and Regulations enforced in India widely support land intensification and aspire to limit urban sprawl (Raman, 2010). Liveability is a collection of ideas with no universally accepted definition. It is multifaceted, made up of diverse criteria and sub criteria, measured in various methods. The idea of liveability varies from culture to culture along with time, and its essence relies on place, period, and purpose. (Khorrami et al., 2020)

The main question arises?

- According to the context, The Rock Fort area not only functions as a CBD but also possesses a compact urban fabric with diverse functional activities, as suggested by modern-day city development. The question arises: Does this diverse context in traditional settlement affect liveability?

- Understanding the issues of traditional urban morphological fabric and gaining knowledge for potential improvements that are likely to contribute to livability.

LITERATURE REVIEW

Form & land use efficiency

Urban form encompasses place, shape, and their relationships with spatial elements i.e., streets, plots and structures, and open spaces (Çalışkan & Şevik, 2022). (Jacobs, 1961) supported dense, mixed design and planning for a flourishing urban society. The efficient function of neighborhoods lies in their relation with design and human activity associated with the physical form of the city. The old urban areas over a period which leads to social and physical issues (Mahmoudi et al., 2015). A livable urban environment is one in which the built form enhances inhabitants' quality of life by satisfying their essential needs (Khorrami et al., 2020). The relevancy of compact settlement living varies according to social and cultural context, being dense will not necessarily imply sustainability or livability. Other physical features of the built environment, such as the distance between buildings, open space ratio, building height, layout, and other related parameters, should be examined (Raman, 2010).

Diverse activities and vibrancy

The high number of people involved in social and economic activities has a significant impact on urban liveliness. (Jacobs,1961). A diverse use, and high density of population contribute to vibrancy (Çalışkan & Şevik, 2022). CBDs' higher-density and diversified environments have also created enormous learning and information-sharing opportunities, which catalyzed innovation and economic productivity (Jha, 2021). Urban vibrancy depends on well-designed and fully engaged citizens and urban facilities (Chen et al., 2021). Vibrancy is a fundamental part of urban quality of life. A lively urban area supported by open areas with high levels of human activity. (Fu et al., 2021)

Accessibility & Inclusiveness

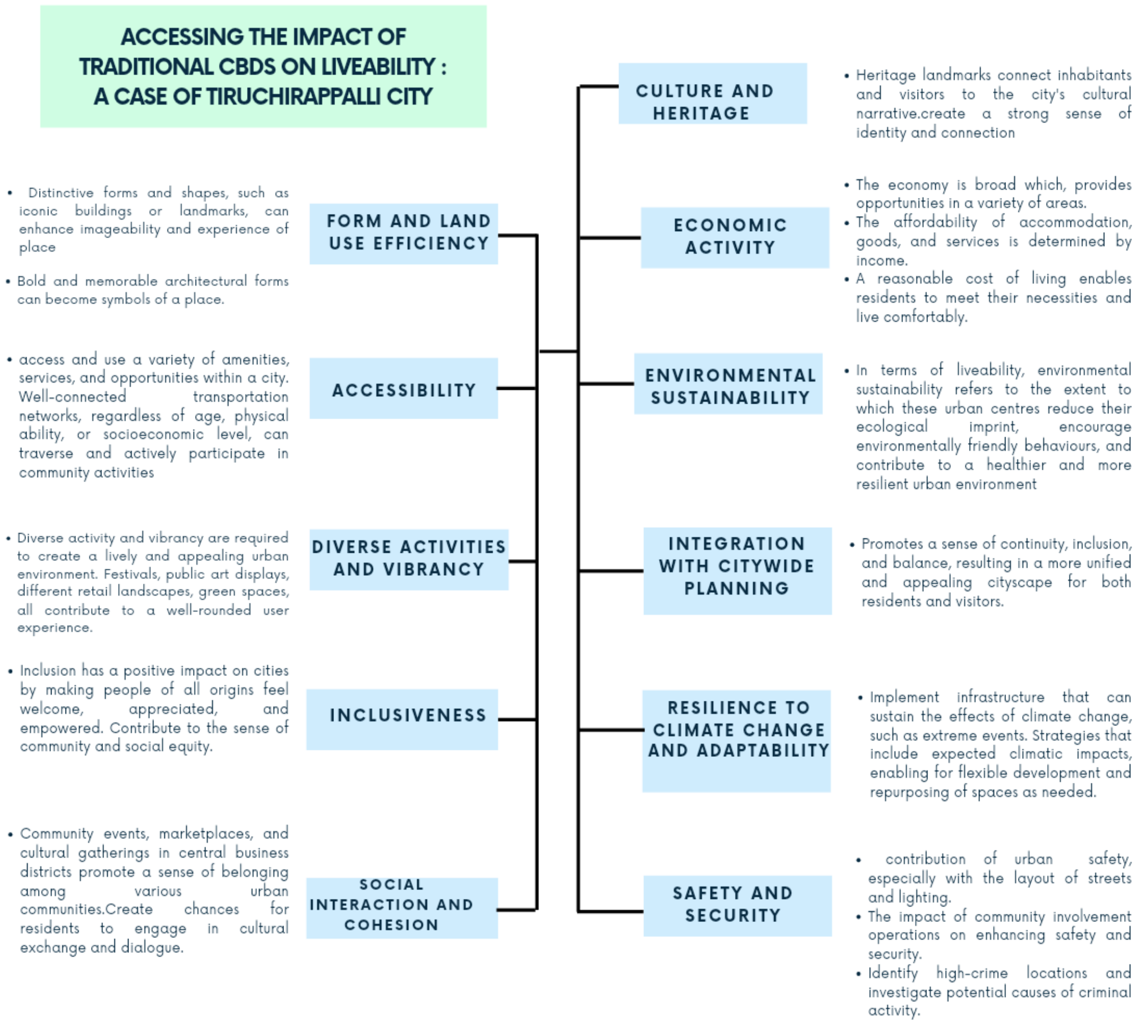
A compact city is considered pedestrian-friendly, offering a contrast to car-dependent urban sprawl. (Burton, 2000). Moreover, the physical qualities of urban areas have an effect on mobility decisions and trends in movement (Raman, 2010). According to (Shamsuddin et al., 2012) Livable city emphasizes transportation sustainability to reduce noise and air pollution. There is a need to understand the connection between transportation and urban layout. Furthermore, high residential density has a significant impact on reducing average journey, and a high employment density is positively connected with average trip length. Attractive neighborhood facilities are considered as a 'pull' element which results in decreasing travel length. (Dieleman & Wegener, 2004) The Development of urban areas or sustainable cities overlooks the people-centered approach (Mahadevia, 2001). According to UN-SDG By 2030, ensure universal access and accessible public places, especially for women and children, the elderly, and those with disabilities (Martin, 2023)

Social Interaction and Safety

Public spaces are an essential component of the urban landscape and act as the foundation for daily function. The most easily accessible public space is streets, which is an important component of livable communities, giving a high quality of life by offering efficient transportation options, housing, jobs, and community interaction (Harvey & Aultman-Hall, 2015). Also, High-density areas have the potential to develop attractive urban areas and promote social cohesiveness by drawing individuals from all demographics (Allen et al., 2018). Robust social connections and a vibrant community contribute to a higher quality of life, and social indicators of neighborhoods, such as low crime rates, economic productivity, and overall well-being, might be connected to social cohesion (Raman, 2010). Diverse social groupings with different agendas and ideals, create a profile of humanity that prioritizes harmony above unification (Bishop & Marshall, 2017).The safety aspects of urban areas are promoted by eyes on the street, also known as the "natural surveillance" an element of Crime Prevention Through Environmental Design. The risk of criminal conduct is substantially related to the presence or absence of people on the street (Humphrey et al., 2019). Alongside crime prevention, traffic management and control by design are additional elements of safe environments (Çalışkan & Şevik, 2022).

Cultural and Heritage

Culture refers to a society's way of life, including conventions of dress, language, religion, rituals, behavior, belief systems, and art. Cultural anthropologists define 'culture' as the ability of humans to categorize and convey their experiences through material and symbolic means (Abdel-Hadi, 2012b). Heritage sites include parks, monuments, religious institutions, educational institutions, and museums that are important to a community's identity. There are numerous types of heritage tourists interested in various aspects of urban culture (Lak et al., 2019). Cultural values are diverse tangible and intangible factors, as well as natural elements of cultural significance, identified by stakeholders with economic, social, ecological, or cultural potential (Hribar et al., 2015).



Environmental Sustainability & Economic Vitality

In an increasingly globalized world, fostering local agriculture and native business entities, urban parks and forests, ecological integrity, and social cohesiveness improves livability while also providing material and intangible advantages to society (Rüth & Franklin, 2014). The ecological component is evaluated at the neighborhood level, however not every neighborhood has open spaces. The distance to the closest park may be used to assess livability (Benita et al., 2020). The economy's efficiency provides workers with timely access to employment centers, education, services, and other fundamental requirements while expanding business access to markets (Gough, 2015). According to Charles Montgomery's book HappyCity, livability is typically included within a larger framework that ensures people feel safe and happy while combating poverty (Montgomery, 2013). The rapid economic changes have significantly affected society, culture, ecosystems, health, justice, and equality (Abdel-Hadi, 2012b).

Integration with the city & Resilience to climate change.

As urbanization rises, larger populations and assets become geographically concentrated and vulnerable to systemic shocks. Urban infrastructures are strained beyond or used above their capacity to satisfy demands (Rüth & Franklin, 2014). Ecology resilience refers to a system's ability to absorb disruption while maintaining its function, order, and character (Holing, 1973). Adaptability concerns social resilience as the ability to deal with external challenges. pressures and disturbances caused by social, political, and ecological change (Tong, 2021). According to the UN SDG by 2030 provide accessible to safe, cheap, accessible, and sustainable transport systems for all, enhancing road safety and expanding public transport, with specific regard to the requirements of those in difficult circumstances, including women, children, people with disabilities, and the elderly (Martin, 2023). Generate base data and information. The implementation of the CPI (City Prosperity Index) allows cities to generate baseline statistics and data, which is critical for redefining local goals, proposing improvement initiatives, identifying setbacks, and tracking progress over time (City Prosperity Index, n.d.)City profile: Tiruchirapalli

Tiruchirapalli, Tamil Nadu's fourth-largest metropolitan city, lies in the state's geographical middle, on the bank of the Cauvery River. Despite tremendous population and size expansion, the city lacks coherent urban planning, resulting in various structures of all sizes and shapes. It is also known for its religious sites, including the Sri Ranganathaswamy Temple, Jambukeshwara Temple, and Rock Fort Temple, which welcome pilgrims all year.

Evolution of Tiruchirapalli

Tiruchirapalli is one of Tamil Nadu's oldest cities, dating back to the Early Cholas, noted by Ptolemy in the second century BC. The capital city of cholas, which was located in its suburb, a place called Uraiyur. After that, Pallava, Pandya, Delhi Sultanate, and Madurai Sultanate ruled until 1378, Then the Vijayanagar Empire annexed them. It eventually formed part of the Madurai Nayak state until 1736, after which it came under Maratha and Carnatic domination. In 1801, the British seized Tiruchirapalli and included it as part of the Madras Presidency. In 1871, it was the second-largest city, with a population of 76,530. Tiruchirapalli was under British dominion for approximately 150 years and played an important role in early railway growth, hosting the headquarters of the Southern Indian Railway of the Bristish.

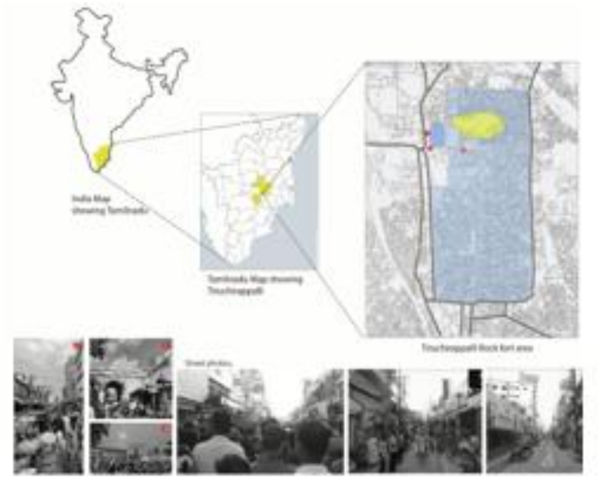


Figure 1. Illustration showing the study area

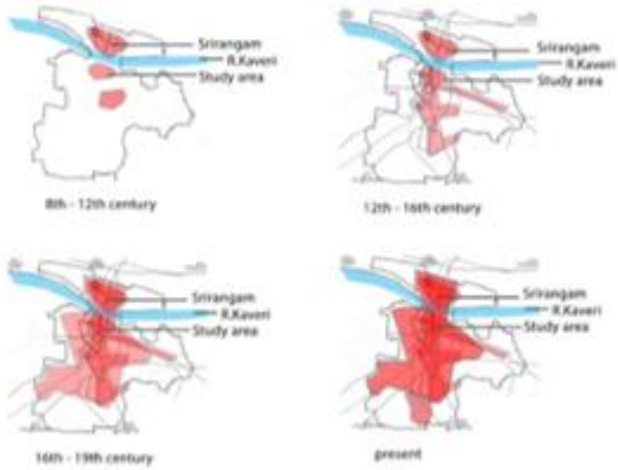


Figure 2. Evolution of the Tiruchirappalli City

METHODOLOGY

For the research on assessing the impact of traditional Central Business Districts (CBDs) on liveability in Tiruchirapalli city, The main survey targeted a broad audience which includes students, residents, and visitors within the CBD as well as those who have experienced the CBD of Tiruchirapalli. Survey participants were asked to rate the livability condition of CBD based on their experience, considering various factors such as physical condition, ease of use, Specific aspects like economy, accessibility, inclusiveness, cultural and heritage significance, climate resilience, urban form, safety, and overall experience were also evaluated. The questionnaire comprised 13 questions; responses were gathered using a five-point Likert scale.

Observation

Direct observation is a method primarily incorporated in the research on assessing the impact of liveability in CBD in Tiruchirapalli. Adopting a walk-by approach initially aims to delineate activity patterns, usage problems, and active locations within the study area. Subsequently, structured direct observations will be conducted to ascertain the duration of street users' visits, identifying the nature of activities (temporary or static) and distinguishing between short-term and long-term engagements. The observation of various times across different parts of the day (morning, afternoon, and evening), provides a comprehensive understanding of how traditional CBDs influence urban life in Tiruchirapalli. The fieldwork, conducted in clear weather conditions, enables a thorough exploration of the city's livability dynamics.

Analysis

Data collected from the survey were processed and analyzed using Excel and SPSS. A correlation test was employed to examine the impact of various tangible and intangible attributes within the CBD areas of Tiruchirapalli city. Aimed to provide insights into the relationship between the quality of traditional CBD and the perceived liveability condition of the urban environment in Tiruchirapalli.

RESULT

Correlations

		Land use efficiency	Vibrancy and attractiveness of the city	Accessibility of markets and essential services	Sense of community and social interaction	Safe neighborhood, public spaces, streets, and residential areas	Preserve cultural heritage and promote cultural activities	Accessible of people with disabilities	Integrate with citywide planning	Economy diversity	Environmental sustainability	Resilience to climate change and disaster	Long-term vision and adaptability	Overall rate on quality of life and livability in your city,
Land use efficiency	Pearson Correlation	1	.028	.158	.405**	.193	.258*	.184	.040	.081	.154	-.078	-.159	.167
	Sig. (2-tailed)		.807	.168	.000	.091	.023	.107	.728	.479	.180	.500	.164	.144
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Vibrancy and attractiveness of the city	Pearson Correlation	.028	1	.056	.171	.043	.272*	.179	-.017	-.017	.112	.138	-.026	.307**
	Sig. (2-tailed)	.807		.626	.134	.706	.016	.117	.884	.882	.327	.227	.819	.006
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Accessibility of markets and essential services	Pearson Correlation	.158	.056	1	.113	.357**	.244*	.135	.114	-.053	.098	.040	-.083	.183
	Sig. (2-tailed)	.168	.626		.325	.001	.032	.238	.320	.647	.394	.726	.470	.109
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Sense of community and social interaction	Pearson Correlation	.405**	.171	.113	1	.301**	.255*	.232*	.312**	.245*	.259*	.167	.128	.366**
	Sig. (2-tailed)	.000	.134	.325		.008	.024	.041	.005	.031	.022	.144	.266	.001
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Safe neighborhood, public spaces, streets, and residential areas	Pearson Correlation	.193	.043	.357**	.301**	1	.433**	.434**	.405**	.227*	.331**	.149	.233*	.499**
	Sig. (2-tailed)	.091	.706	.001	.008		.000	.000	.000	.046	.003	.193	.040	.000
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Preserve cultural heritage and promote cultural activities	Pearson Correlation	.258*	.272*	.244*	.255*	.433**	1	.573**	.403**	.268*	.403**	.124	.141	.368**
	Sig. (2-tailed)	.023	.016	.032	.024	.000		.000	.000	.018	.000	.281	.217	.001
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Accessible of people with disabilities	Pearson Correlation	.184	.179	.135	.232*	.434**	.573**	1	.478**	.230*	.225*	.227*	.289*	.432**
	Sig. (2-tailed)	.107	.117	.238	.041	.000	.000		.000	.043	.047	.046	.010	.000
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Integrate with citywide planning	Pearson Correlation	.040	-.017	.114	.312**	.405**	.403**	.478**	1	.300**	.251*	.316**	.194	.361**
	Sig. (2-tailed)	.728	.884	.320	.005	.000	.000	.000		.008	.027	.005	.089	.001
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Economy diversity	Pearson Correlation	.081	-.017	-.053	.245*	.227*	.268*	.230*	.300**	1	.174	.061	.103	.199
	Sig. (2-tailed)	.479	.882	.647	.031	.046	.018	.043	.008		.127	.595	.369	.081
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Environmental sustainability	Pearson Correlation	.154	.112	.098	.259*	.331**	.403**	.225*	.251*	.174	1	.310**	.045	.398**
	Sig. (2-tailed)	.180	.327	.394	.022	.003	.000	.047	.027	.127		.006	.695	.000
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Resilience to climate change and disaster	Pearson Correlation	-.078	.138	.040	.167	.149	.124	.227*	.316**	.061	.310**	1	.172	.264*
	Sig. (2-tailed)	.500	.227	.726	.144	.193	.281	.046	.005	.595	.006		.131	.020
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Long-term vision and adaptability	Pearson Correlation	-.159	-.026	-.083	.128	.233*	.141	.289*	.194	.103	.045	.172	1	.138
	Sig. (2-tailed)	.164	.819	.470	.266	.040	.217	.010	.089	.369	.695	.131		.229
	N	78	78	78	78	78	78	78	78	78	78	78	78	78
Overall rate on quality of life and livability in your city,	Pearson Correlation	.167	.307**	.183	.366**	.499**	.368**	.432**	.361**	.199	.398**	.264*	.138	1
	Sig. (2-tailed)	.144	.006	.109	.001	.000	.001	.000	.001	.081	.000	.020	.229	
	N	78	78	78	78	78	78	78	78	78	78	78	78	78

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Description of Result

- Land Use efficiency correlates significantly with a Sense of community and social interaction
- Vibrancy and attractiveness of the city are significantly correlated with Overall quality of life and livability
- Accessibility of essential services significantly correlates with Safe neighborhoods,
- Sense of community and social interaction

significantly correlate with a Safe neighborhood and integrate with the broader citywide planning goals, Overall quality of life, and livability.

- Safe neighborhoods significantly correlate with preserving cultural heritage and promoting cultural activities, Accessibility to individuals with disabilities, Integration with the broader citywide planning goals, environmental sustainability, Overall quality of life, and livability
- Preserving cultural heritage and promoting cultural activities have significant correlations with Accessibility to individuals with disabilities, Integration with the broader citywide planning goals, environmental sustainability, Overall quality of life, and livability.
- Accessibility to individuals with disabilities significantly correlates with integration with the broader citywide planning goals, Overall quality of life, and livability.
- Integrate with the broader citywide planning goals has a significant correlation with Economic diversity, Resilience to climate change and disaster, and Overall rate of quality of life and livability in your city.
- Environmentally sustainable has a significant correlation with Resilience to climate change and natural disasters, Overall quality of life, and livability.

DISCUSSION

The correlations identified in the study highlight important connections between various factors and their impact on livability in Tiruchirapalli city. These findings suggest that aspects like land use efficiency, sense of community, and accessibility to essential services will play a crucial role in a rapidly growing city's urban livability. This research suggests that a comprehensive approach to urban development, encompassing land use efficiency, safety, cultural preservation, and environmental sustainability, is essential for enhancing the city's historic richness of tangible and intangible assets while at the same time promoting the liveability of Tiruchirapalli. These correlations provide valuable insights for policymakers and urban planners to make informed decisions for the city's sustainable and livable future. Furthermore, research is carried out on the factors suggested by the research in detail concerning urban planning principles, which will help the city flourish forever.

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Understanding Psychology of the User's Behaviour in Public Buildings

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Abstract —The study of architecture shapes the environments in which people live, work, and interact. This research paper delves into the critical field of psychology in the context of users of public buildings, describing the complex interplay between users' psychological welfare and architectural decisions. This research paper aims to explore the fundamental design ideas and the historical study that highlights the development of the psychology of the user's behavior in public buildings with its incorporation into user-centric methodologies and looks at how designers and architects can use psychology to make environments that are more than just functional and promote positive experiences for a range of user groups in public buildings. The importance of user-centered design ideas is established at the paper's outset. It examines how an awareness of a user's behavior and cognition influences architectural decisions, resulting in public buildings that are not only aesthetically pleasing but also intuitively practical. Subsequently, this study looks into how psychology affects users' experience in public buildings. This research paper explores how architects improve the entire user experience by taking emotional and cognitive reactions into their design considerations. In this research paper, cultural and socioeconomic effects on psychology are highlighted, providing insight into how architects incorporate cultural sensitivity into the designs of public buildings. This research paper delves deeper into the users' effective and mental reactions to architectural features in public buildings. This research paper explores the analysis of architectural forms, spatial organization, and color psychology, and also presents how these factors contribute to the overall atmosphere and affect users' mental and emotional states. As sustainability gains importance in today's architectural discourse, this study clarifies how sustainable design and psychological effects are mutually beneficial. Environmentally responsible decisions not only support ecological responsibility but also positively impact users' well-being in public buildings. The research paper delves into how architects utilize innovations to landscape settings that adjust to the requirements of their users. Psychological research informs human-centered design interfaces, which improve public buildings' general usability and accessibility showcased with the case study of Swaminarayan Akshardham Temple (New Delhi) constructed in 2005, Lotus Temple (New Delhi) constructed in 1986, and Jawahar Kala Kendra (Jaipur, Rajasthan) constructed in 1991. The research paper concludes the user's behavior in architectural practice by providing a thorough analysis of the subject for users of public buildings. Through the adoption of user-centered design principles, cultural sensitivity, and sustainable practices, architects skilfully manage the intricate interplay between functionality and aesthetics, that not only fulfil practical needs but also the varied psychological experiences of the people they work with and live in.

Keywords: User-Centric, Psychology, Accessibility, Behavior, Public Building

INTRODUCTION

This research endeavours to unravel the psychology of users in public buildings, delving into the realms where design decisions and human experiences converge. Beyond simple structural beauty, architecture is a discipline that permeates all aspects of our lives, affecting how we work, communicate, and find comfort in public areas. The central theme of our investigation—a psychological examination of the people who occupy these public spaces—lies inside this tapestry. Our study sets out on a voyage across the history of design, following the development of user-centric approaches. Its goal is to not only comprehend the fundamental ideas that underpin the psychology of user behavior but also to shed light on how to design environments that go beyond simple utility and promote positive experiences for a wide range of user demographics.

The recognition of the critical role that user-centered design principles play is at the core of this investigation. The deep influence of an architect's understanding of human behavior and cognition becomes evident when we lift the layers of architectural decision-making. Public buildings are transformed into intuitively functional environments that resonate with the lived experiences of their users by this knowledge, which serves as a beacon directing the design process.

The symbiotic interaction between psychology, culture, and socioeconomic issues is further explored in this research. It clarifies how cultural sensitivity is incorporated into architectural designs by architects who understand the significant influence of social subtleties on user experiences. The study explores the complex relationship between users' emotional and cognitive responses to architectural elements, looking at form analysis, spatial organization, and color's psychological effects. The relationship between sustainable design and psychological well-being is becoming more transparent as the architectural discourse embraces sustainability. In addition to meeting ecological requirements, the article shows how ecologically conscious decisions can improve public venues' overall user experience.

Case studies of famous buildings like Jawahar Kala Kendra, Lotus Temple, and Swaminarayan Akshardham Temple are incorporated into this investigation. These case studies act as benchmarks, demonstrating how psychological research influences human-centered design interfaces and improves public building usability and accessibility.

Background study

The complicated link between architectural design and people's psychological well-being in public buildings is the topic of this research paper. (Learn about the fundamentals of design psychology and environmental psychology with a focus on how design affects human behavior and well-being) (Kaplan, S., & Kaplan,1989). (Examine studies and hypotheses about user experience in a variety of public structures, such as libraries, museums, hospitals, and civic places) (Zeisel, J.,2006). Understanding how the built environment affects users' feelings, actions, and experiences is crucial for designing spaces that meet the wide range of needs of the general public. This study explores the area of design psychology to learn more about how the aesthetics of public spaces affect people's cognitive and emotional reactions, levels of satisfaction, and general well-being. It also seeks to determine the amount to which cultural issues, accessibility, inclusion, and aesthetics all influence how users perceive and behave in these settings. The research paper intends to provide insightful contributions.

Objective

- Examine the practical aspects of accessibility and inclusivity in the design of public buildings.
- Studying suggestions that architects, designers, and decision-makers may implement to improve public building design.
- To gauge user happiness and well-being.
- Studying patterns of human behavior in public spaces will help designers better understand how people move through, interact with, and use space.

LITERATURE REVIEW

Human Behavior in Public Buildings

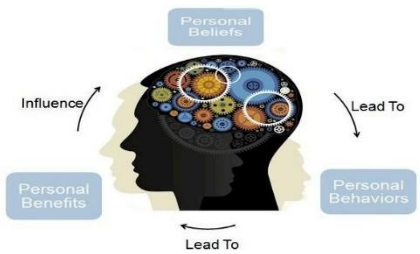

Figure 1: Human Behaviour, reference: Kaplan et al., 1989

Studies that shed light on how spatial organization and design elements affect behavior include "The Influence of the Built Environment on Human Behaviour: A Study of Space and Place" by Gary T. Moore and Robert W. Marans. These insights can be used by architects to design public spaces that facilitate the intended interactions and activities.

Application: By incorporating knowledge from studies such as Moore and Marans', architects can create public structures that have a good behavioural impact on people. When designing spaces, factors like illumination, accessibility, and spatial organization come together to help encourage the kinds of behaviours and activities that are wanted.

(Biophilic design principles highlight the psychological impacts of bringing nature into the built environment. They are discussed in "Biophilic Design: Theory, Science, and Practice" by Stephen R. Kellert and Judith H. Heerwagen. Natural features including vegetation, water features, and natural light can improve cognitive performance and emotional well-being in public buildings.) (Kellert, Heerwagen, and Mador, 2008, n.d.)

Impact of Design on User Well-being

The well-being of users is greatly impacted by architectural design, and biophilic design is one important strategy. (Natural light, vegetation, and vistas of the outdoors are examples of elements that can enhance mood, lower stress levels, and promote general well-being. The psychological advantages of applying biophilic principles are explained by research by Kellert and colleagues in "Biophilic Design: The Theory, Science, and Practise of Bringing Buildings to Life.") (Kellert, Heerwagen, and Mador, 2008, n.d.)

Design aspects' Emotional Impact:

(Different design aspects elicit different emotional reactions. Warm colors, for instance, might produce sentiments of coziness and comfort, while open, airy environments can evoke sensations of relaxation and freedom. Architects can deliberately create environments that correspond with the desired emotional experiences of users of public buildings when they have a thorough understanding of the psychological reactions to various design aspects) (Salingaros, 2020).

Cultural Aspects in Design:

Cultural factors also have an impact on how well users are served by designs. (Aesthetic conventions, cultural preferences, and symbolism all influence how people react to design features. Culturally sensitive design takes these aspects into account and honors them, making public structures appealing to a wide range of users of public buildings.)(S. Kaplan & Kaplan, 1989)

Well-being through Holistic Design:

User-centered design concepts give end users' requirements, preferences, and well-being a top priority. This methodology entails involving users at every stage of the design process, taking their input into account, and taking into account the various ways that people interact with and interpret the built environment. The creation of environments that improve user well-being is consistent with the tenets of user-centered design.

Evaluating User Experience and Satisfaction:

These two factors are crucial for determining whether architectural design is successful in fostering well-being. (User surveys and post-occupancy evaluations (POEs) offer important insights into how well-designed places affect users' day-to-day lives. Research works such as Zeisel's "Inquiry by Design: Tools for Environment-Behavior Research" offer methods for evaluating user satisfaction and help architects refine their ideas in response to actual customer feedback.)(Zeisel, J., 2006, n.d.) The function of design in creating positive user experiences is multifaceted, ranging from the use of biophilic design concepts, which integrate nature into constructed spaces, to the psychological reactions elicited by aesthetic components. Understanding how design decisions might improve the general well-being of varied user groups is further enhanced by taking cultural factors and user-centered design principles into account. By incorporating these principles, architects can design public buildings that improve the overall well-being of those who occupy them in addition to fulfilling functional needs.

Views of Nature:

Studies have shown how views of nature can improve mental health. (One such study is "View through a Window May Influence Recovery from Surgery," conducted by Roger Ulrich. Architects can positively impact tenant experiences in public buildings by strategically placing windows and providing visual access to nature.) (Ulrich, 1984)

Reducing Stressors:

The connection between environmental stress and health, emphasizes how crucial it is to reduce stressors like noise to improve user comfort. Architects can use stress-reduction techniques and the creation of surroundings that promote mental and emotional health while designing public buildings.

(Applying knowledge from basic research to design public buildings that meet human psychological requirements is known as environmental psychology. Architects can improve user pleasure and well-being in public buildings by incorporating biophilic components that promote a connection to nature or by influencing human behavior through spatial organization.)(Carlsson et al., 2022) This method helps to create environments that support the many psychological experiences of their occupants in addition to being functional.

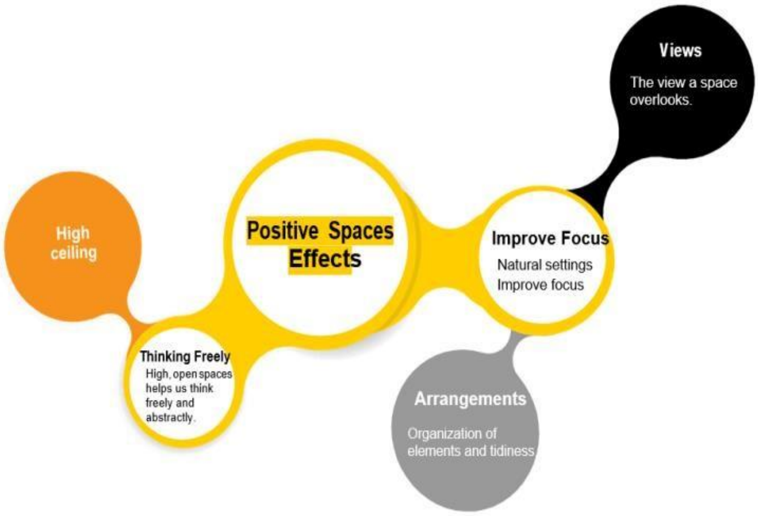

Figure 2: Positive space effects, reference: Melhuish, 1973

Cultural and Societal Influences on Design Psychology

Cultural Sensitivity in Design:

The field of design psychology acknowledges the significant impact that cultural factors have on people's perceptions of and interactions with their environment. (Culturally sensitive design must take into account the various conventions, values, and aesthetics of other cultures. To design environments that are in line with the identities and preferences of various user groups, this recognition is essential.) (Carlsson et al.,

2022)

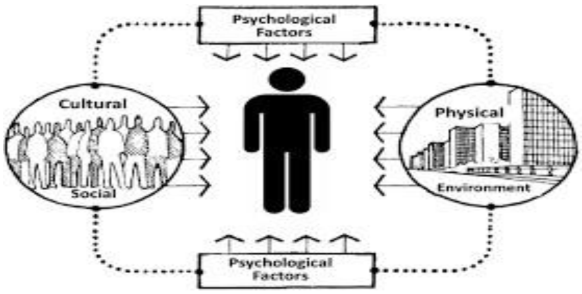

Figure 3: Psychological factor, reference: (Salingaros, 2020)

Architectural Expression of Identity:

Architecture serves as a powerful expression of cultural identity. Public buildings often become symbols of cultural heritage and values. Whether incorporating traditional design elements or adapting modern architectural styles to reflect cultural identity, architects can contribute to a sense of place and belonging within a community.

Spatial Configuration and Social Practices:

(Cultural influences extend to spatial configurations within public buildings. Societal norms and social practices shape how people interact in shared spaces.) (S. H. Kaplan et al., 1989) Understanding these cultural dynamics allows architects to design layouts that facilitate social interactions or provide private, contemplative spaces based on cultural expectations.

Designing for Diverse User Groups:

Cultural and societal influences highlight the diversity of user groups within a community. Inclusive design principles, emphasize creating environments that accommodate individuals with diverse abilities, backgrounds, and ages. This approach ensures that public buildings are accessible and welcoming to everyone.

Community Engagement in Design:

(Engaging with the local community during the design process is essential. Understanding community needs, aspirations, and cultural nuances allows architects to co-create spaces that genuinely reflect and serve the community.) (Mohr et al., 2009) Community involvement fosters a sense of ownership and pride in public buildings.

Ethical Considerations in Design

Designing Ethically and Responsibly:

Cultural and societal influences also extend to ethical considerations in design. Architects must be aware of the potential impacts of their designs on communities, considering factors such as environmental sustainability, social equity, and historical preservation. Ethical design practices contribute to responsible and socially conscious architecture.

Balancing Tradition and Innovation:

Architects often navigate the balance between preserving cultural traditions and embracing innovation. Finding harmony between the past and the present allows for the creation of buildings that respect cultural heritage while addressing contemporary needs. This delicate balance contributes to the timelessness and relevance of public buildings within evolving societies. the intricate interplay between cultural and societal influences on design psychology. (From understanding cultural contexts and expressions of identity to embracing inclusive design principles and ethical considerations, architects can create public buildings that not only serve functional purposes but also contribute positively to the cultural fabric and social dynamics of communities. Recognizing and incorporating these influences enriches the design process, fostering environments that resonate with the diverse identities and values of users.) (Mahmoud, 2017)

Factors Affecting Emotional and Cognitive Responses of Users in Public Buildings

Aesthetic Elements and Emotional Impact

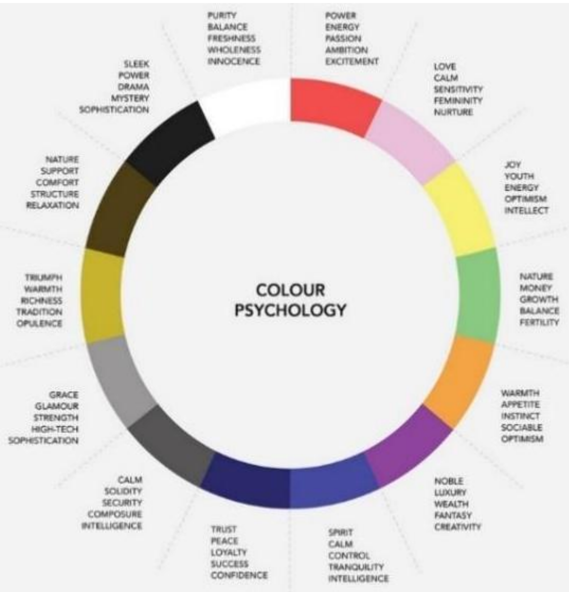

Figure 4: Colour Psychology, reference:

(**Colour psychology:**

Colour selection has a significant effect on how people feel about buildings. While cool hues like blues and greens may encourage serenity and relaxation, bright hues like reds and yellows can arouse sensations of warmth, enthusiasm, and excitement. Architects can design environments that cause inhabitants to experience particular emotions by having a thorough understanding of color psychology.) (Rosen & Purinton, 2004)

It's beneficial to consult authorities and writers on the subject when digging into the specifics of color psychology in public spaces. Here is a more thorough investigation that includes some noteworthy references:

Entryway/Seating Area:

(Blue: According to studies conducted by environmental psychologist Dr. Sally Augustin, using blue in entry areas makes sense. As she explains in her book "Place Advantage," blue is a great color for inviting environments because it inspires feelings of trust and security.) (Dr. Sally Augustin, 2016).

Waiting Sections:

(Green: Environmental psychologist Rachel Kaplan talks at length about how green may be comforting. Her writing, which includes the book "With People in Mind," emphasizes how invigorating and stress-relieving flora is, which makes it a good choice for waiting rooms.) (R. Kaplan, 2001a)

Office/Workspace Spaces:

Yellow: The beneficial effects of yellow on creativity are investigated.

Conference Rooms:

(Red: According to color expert Faber Birren, who is well-known for his contributions to color psychology, red can arouse emotion and conversation (see "Colour Psychology and Colour Therapy") (Faber Birren, 1976). It can be deliberately used in conference rooms to promote lively and thought-provoking conversations.

Cafeterias and break areas:

Orange: According to research conducted by Frank H. Mahnke, the International Association of Colour Consultants' director, orange promotes warmth and sociability. Mahnke's work, "Colour, Environment, and

Human Response," delves into how orange might improve the communal vibe in break rooms. (Frank H. Mahnke, 1996)

Still/Meditative Areas:

(Purple: Colour psychology pioneer Dr. Max Lüscher has talked about how purple is a relaxing and reflective color. In "The Lüscher Colour Test," he explores how purple may be used to produce a reflective and peaceful atmosphere.)(Melhuish, 1973a)

Material Selection:

Emotional reactions are also greatly influenced by the materials used in architecture. Warmth and a sensation of being in one with nature can be evoked by natural materials like stone and wood. Luxurious and comfortable environments are enhanced by the use of premium, tactile materials. A space's overall atmosphere is improved when the chosen material selections are in harmony with the intended emotional tone.

Spatial Layout and User Experience:

Organization and Flow of Space: How a building's spaces are arranged affects how people move through and interact with it. While delineated rooms might offer a sense of seclusion and focus, open layouts may encourage a sense of connectivity and collaboration. To create spaces that accommodate a variety of activities and user preferences, architects take into account how spatial organization elicits particular cognitive reactions.

Figure 5: Psychological effect of light on human behaviour, reference 5: Rosen & Purinton, 2004

Lighting Design:

For both cognitive and emotional reactions, lighting design is essential. Positive emotional experiences are enhanced and well-being is promoted by natural light. Artificial lighting with purpose can be used to draw attention to certain areas, accentuate architectural details, and change how space is perceived. An atmosphere that is harmonious and aesthetically pleasing benefits from the balance of natural and artificial light.

Form and Architectural Expression:

Architectural Shapes and Symbolism: Architectural shapes and forms can arouse particular feelings and have symbolic value. For instance, angular and dynamic designs may communicate energy and excitement, while curved and organic forms may evoke a sense of harmony and relaxation. Using these symbolic connections, architects create structures that convey meaning and elicit strong emotional responses from their occupants.

How Understanding Psychology of the User's Behaviour in Public Buildings enriched the theoretical understanding of architecture.

- User-Centered Focus: Psychology in architecture shifts from architect-centric to user-centric design, emphasizing human behavior, preferences, and needs.`
- Emotional and Cognitive Impact: Theoretical understanding expands to include the study of emotional and cognitive responses to architectural elements, going beyond traditional formalism.
- Cultural Sensitivity: Psychology acknowledges cultural influences on behavior, enriching architectural theory with recognition of diverse human experiences.
- Spatial Organization Insights: Psychological insights inform spatial organization theories, incorporating concepts like wayfinding and spatial hierarchy.
- Color Psychology: Architecture considers color beyond aesthetics, integrating theories on how color impacts users' mental and emotional states.
- Sustainable Design and Well-Being: The link between sustainable design and human well-being is emphasized, contributing to a more comprehensive architectural theory aligned with societal goals.
- Human-Environment Interaction Studies: Architectural theory incorporates environmental psychology methodologies, studying the complex relationship between humans and their surroundings.
- Empirical Validation: Theoretical advancements often involve empirical studies and case analyses, promoting evidence-based design and refining theories through real-world validation.

CASE STUDIES

Swaminarayan Akshardham, New Delhi

Project details

- Location: Noida Mor (Intersection of NH-24 and Noida Link Road), Delhi Site Area: 40 hectares Built-up area: 32,300 sqm.
- Architect: (unknown) claimed to be designed by Sanstha's top members
- Completed in November 2005
- Client: BAPS Swaminarayan Sanstha

Figure 6: Akshardham Temple, Reference :(https://www.easemytrip.com/blog/akshardham-temple-delhi-information)

Connectivity & Access: Being at a busy junction makes it easily accessible from most sections of the city. Public transport: 350 meters distant from the DTC bus stop and the Blue Line Akshardham Metro station.

As a very successful example of religious heritage tourism in the Indian context, this case study can help understand the tactics involved in providing a delightful user experience and educating tourists. It successfully imparts traditional Indian culture and values to the younger generation through attractions, IMAX theatres, and animatronics. It showcases Bhagwan Swaminarayan, the founder of the organization, and his life's work. It is also possible to view the Akshardham Temple as a symbol of religious and cultural values due to its elaborate embellishments and symbolic components. During a visit, interacting with these symbols and tales may make one feel more connected to their cultural or religious identity, which may have psychological effects.

Furthermore, ritualistic activities that are frequently connected to houses of worship, including prayer and meditation, might be beneficial psychologically. These exercises are proven to promote attention, awareness, and serenity—all of which are beneficial to mental health.

Lotus Temple

S.No.	Details	Details
1.	Architect	Fariburz Sahba
2.	Structural Designer	Flint & Nail Flint and Nail partnership of London were the consultants
3.	Designed in	1976
4.	Designed For (In Year)	200 Year
5.	Built Time Period	1978-1986
6.	Constructed By	ECC Construction (Group of Larsen & Toubro Limited were the contractors responsible for constructing the lotus temple.)
7.	Total site area	24 ACRES/105000 SQ.M.
8.	Setting capacity	1300 people
9.	Climate:	Tropical with great variations in temperature
10.	Building type time of construction	Worship place

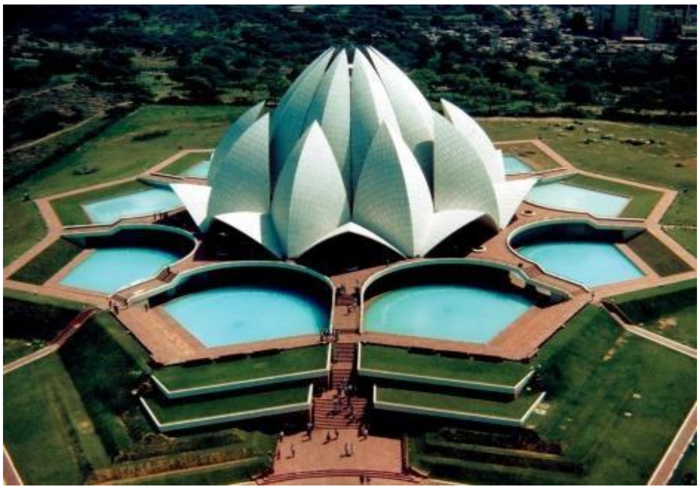

Figure 7: Lotus Temple, reference: (https://sacredsmokeherbals.com/how-tall-is-the-lotus-temple/)

Project details

Its flower-like shape gave rise to the Lotus temple. Another name for Lotus Temple is "BAHAI House of Worship/BAHAI FAITH." The temples in Delhi are a continuation of the long legacy of temples, which are renowned for their architectural magnificence. (This is a well-known Delhi attraction. It is the mother temple of the Indian subcontinent and was finished in 1986. The temple's architecture is reminiscent of a half-opened lotus flower floating among its leaves. People of different languages, cultures, and faiths are welcome to enter the temple. It is a representation of a united India.) (Sahil & Kothari, n.d.)

The Lotus Temple's architectural design, inspired by the lotus symbol, embodies psychological principles in public building creation. Symbolism evokes purity and enlightenment, influencing users' emotions. Its inclusive design, harmonizing with nature, and cultural sensitivity resonate with psychology, fostering a positive, contemplative atmosphere. Thoughtful spatial organization and an avoidance of religious specificity enhance the user experience. The Lotus Temple exemplifies how integrating psychology into architecture goes beyond aesthetics, creating spaces that cater to diverse psychological needs and experiences.

Jawahar Kala Kendra by Charles Correa

Figure 8: Jawahar Kala Kendra

Reference : (https://www.linkedin.com/pulse/charles-correa-masterpiece-jawahar-kala-kendra-jaipurankit-sharma)

Project details

- Project: Jawahar Kala Kendra
- Location: Old city of Jaipur, Rajasthan- India
- Period of Construction: 1986-1991
- Architect: Charles Correa
- Client: Rajasthan Government, India

One of the outstanding examples of Indian modern architecture is "Jawahar Kala Kendra" (JKK), which was constructed in Jaipur, a planned historic city. Through the use of varied materials and space arrangements, modernism and history are blended in this building. As stated by Charles Correa in an interview with RIBA President Angela Brady,("The city itself inspired the design of JKK, with its nine squares symbolizing the nine planets each." The ruler who constructed the city was likewise fixated on the sky; so, he employed the oldest sky myths, such as the "Navgrah" (the nine planets), on the one hand, and created the most recent beliefs, such as science, through the use of astronomical instruments, on the other.) (Correa & Kendra, n.d.)

Cultural Sensitivity:

Jawahar Kala Kendra's architecture is inextricably linked to the traditions of Rajasthan and Jaipur. A feeling of connection and affinity with the users' cultural background is fostered by the use of traditional design cues and regional materials. This could cause a pleasant psychological response that fosters a sense of affiliation and belonging.

Spatial Variety:

A variety of user preferences are accommodated by the complex's several spaces and network of courtyards. While some people might enjoy wide, open spaces, others could be more comfortable in more personal, private situations.

CONCLUSION

This research paper concludes the integration of psychology and architecture in public building design has fundamentally changed our knowledge of architectural philosophy. This multidisciplinary approach breaks through conventional paradigms by centering the design process around the needs and preferences of users. It explores the cultural, emotional, and cognitive aspects of human behavior, adding a comprehensive viewpoint to architectural theory. The focus on sustainable design improves user well-being in addition to being in line with ecological responsibilities. Case studies such as Jawahar Kala Kendra, Lotus Temple, and Swaminarayan Akshardham Temple provide concrete proof of how psychological insights are reflected in architectural settings. This research paper emphasizes that architecture is a comprehensive investigation of the human condition rather than only a study of structures. Architects that embrace psychology create environments that are not just functional but also speak to the variety of psychological experiences that people have when using and engaging with public buildings.

CONFLICTS OF INTEREST

No conflicts of interest were declared by the authors.

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Sensory Experiences in the Built Environment

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Abstract— Architecture has the power to impact our lives in various ways. The most interesting aspect lies in the interactions of a space to make it more experiential and memorable. The experiences in the early stages of lives are so deeply imbibed in the senses that they stay forever in the mind. There is an interplay between our senses through which we understand and respond to our surroundings. Skillful composition of design elements creates spatial harmony, much like a chef's balance of flavors in a dish. Beyond mere visual perceptions, various senses converge to create feelings, form memories, capture sounds, and much more. A survey of 110 architects highlights their perceptions about integration of sensory elements in the built environment. Preliminary findings suggest rich considerations within architectural practice, emphasizing the significance of sensory design. The case studies examine selected architectural projects renowned for their innovative approaches to sensory engagement. The exploration of design elements such as scale-proportions, light, and texture reveal their profound impact on human perception and well-being. In an urbanized world, the integration of thoughtful sensory design emerges as a critical aspect of creating spaces that positively influence the human experience. This research contributes insights on enhancing the quality of built spaces by harnessing the power of sensory engagement.

Keywords: Senses; Multi-sensory Design; Experience; Built environment; Light in architecture

INTRODUCTION

“Most of us all walk around as if we're sleepwalking. We really don't experience the world fully, because we're half-asleep, doing things we automatically think we have to do.” -Mitch Albom

The human sensory system comprises of five faculties: visual perception, auditory experience, olfactory awareness, gustatory sensations, and tactile responses. However, architectural design tends to disproportionately prioritize the visual sense, often surpassing the significance of our other senses restricting the experiential engagement. (Zaredar, 2015)

According to Helig’s hierarchy of sensory preferences, vision takes precedence at 70%, followed by audition at 20%, olfaction at 5%, touch at 4%, and taste at 1%. (Spence, 2020A)

We comprehend architectural structures by these sensory inputs. The combination of these senses occurs through logical thinking and reasoning. Our experiences are stored in both long-term and short-term memory systems. Deep within our inner selves lies absolute consciousness laced with emotions. (Ragavendira, 2017)

Our perception of the world around us is entirely facilitated by our sensory faculties, shaping how we understand and engage with our surroundings. These logical operations rely on our sensory inputs, without which our brain's other capabilities would remain passive. (Zaredar, 2015) It is the responsibility of the architects to incorporate elements that make the buildings more appealing. These interactions with the environment have a significant influence over human experiences, shaping our perceptions. The blend of all five senses in a space can strengthen it with spirit and bring a space to life. This approach ensures that both the physical form and functional essence of architecture can be genuinely expressed, enabling users to form meaningful interactions. (Matheny, 2016)

LITERATURE REVIEW

The primary objective of the literature is to create an understanding of the subject matter. Initially, research papers and documents are chosen based on relevant insights, theories, methodologies, and findings as listed in Table 1.

Table 1:Research papers for literature review

Sr. No.	AUTHOR/ YEAR	TITLE	REMARKS
1	R. Ragavendira/ 2017	Architecture and Human Senses	The paper explores how architecture influences human senses, emphasizing their crucial role in spatial design. It highlights the importance of integrating all senses to improve user experience.
2	Arezou Zaredar/ 2015	Considering the Five Senses in Architecture	The research paper explores the role of sensory perception, parameters in architecture and explains their mutual influence amongst the senses. The paper also provides various examples that prioritize sensory experiences.
3	Lisa Wastiels, Hendrik N.J. Schifferstein, Ine Wouters, Ann Heylighen/ 2013	Touching Materials Visually: About the dominance of vision in Building material assessment	The literature explores how different materials influence human perception by visually and tactilely comparing them. This analysis provides insights into how diverse architectural structures shape sensory experiences according to human perception.
4	Aparna Reghukumar/ 2019	Sense and Sensitivity in Architecture: The Use of Five Senses in Space making	The paper focuses on phenomenology's role in sensory experiences in architecture, emphasizing sensory design's impact on emotions, efficiency, and its significance for individuals with special needs.
5	Charles Spence/ 2020	Senses of place: architectural design for the Mind	The research questions the common emphasis on visual aspects, urging recognition of the role our other senses play in perception. This awareness is crucial in architectural design to create environments conducive to well-being, considering our prolonged exposure to built spaces.
6	M.Rathod, Dr. U. Chakradeo/ 2019	Experiencing Architecture through Olfactory Sense	The paper focuses on the significant influence of smell on our experiences, examining examples like the Swiss Pavilion in Hanover and Vaux le Vicomte in France. It delves into how different scents from materials shape human perception.
7	Panagiotis Hadjiphilippou/ 2013	The contribution of five human senses towards the perception of space	The paper explores the importance of human senses in architecture and spatial design, particularly in aiding individuals with sensory impairments like deafness and blindness to understand and interact with their surroundings.
8	Charles Spence/ 2020	Using Ambient Scent to Enhance Well-Being in the Multisensory Built Environment	This review examines how scents in built environments affect user behavior, citing instances of sick building syndrome linked to unusual odors. It discusses the manipulation of scents to influence emotions, exploring categories like stress-inducing scents, ambient fragrances, and signature scents.
9	Roland W Fleming, Shin'ya Nishida, Karl Gegenfurtner/ 2015	Visual Perception of Materials: the Science of Stuff	This study recognizes how materials in our surroundings impact our memory and shape our perception when encountering similar materials. The author highlights our capacity to form an impression of a material's nature before direct interaction.
10	Wouter M. Bergmann Tiest/ 2010	Tactual Perception of Material Properties	This paper examines how tactile perception of materials is understood through qualities like flexibility, texture, resistance, and temperature, offering insights for complex design decisions. The study uses manufactured surfaces to analyze the impact of individual factors under controlled conditions.

The fundamental five senses play a crucial role in the architectural framework. These essential senses encompass in hierarchical order of dominancy i.e. vision, hearing, smell, touch, and taste. What we glean from the readings is that human senses, perception, the quality of space, and the sense of place are intricately interwoven. This interconnectedness hinges on our senses, perceptions, as well as factors such as scale, material, temperature, sound, and more, which influence the spatial quality.

The five senses

The fundamental five senses – visual, auditory, taste, smell, and touch – serve as crucial tools for perceiving our environment, influencing our memories, experiences, feelings, and decisions. (Ragavendira, 2017)

Vision

Vision plays a paramount role in perception within the built environment, it has the capacity to influence our other senses. (C.N. & Nair, 2014) Visual perception collaborates harmoniously with our other senses. What the eyes behold, the rest of our senses validate. (Safrilia, et al., 2017)

- Colours like blue, blue-green, green, red-purple, purple, and purple-blue are found to be the most appealing. Whereas, yellow and green-yellow are typically considered the least pleasing. (Valdez & Mehrabian, 1994)
- Various physical attributes like, enclosed spaces with lower ceilings tend to influence decision-making and the perception negatively, while spaces with curvilinear designs are generally perceived as more aesthetically pleasing. (Bower,

et al., 2019) On the other hand, angular shapes, often associated with sharpness, trigger a defensive response to fight perceived threats posed by their form. (Spence, 2020A)

- Observing natural landscapes or green spaces from within an enclosed environment has a soothing effect. (Ko, et al., 2020) Exposure to natural surroundings provides a restorative experience (Karmele, et al., 2019)
- Different materials evoke specific emotions like, concrete conveys imparts a sense of security, uniformity, and rigidity; wood evokes feelings of comfort and coziness; stone elicits a confident and rugged sensation; bamboo can help alleviate stress and reduce anxiety, promoting both physical and mental relaxation (Zaidi, 2020)
- Visual texture in an environment can influence the perception of users in various ways, rooms with textured walls tend to appear smaller in size. (Wang, et al., 2020); smooth textures can evoke a sense of serenity. (Khatri, 2019); irregular geometric patterns create a dynamic feeling. (Khatri, 2019)

Audition

Sound, even in the absence of visual cues, helps in our understanding of a space. The adjustments in acoustics can have a substantial influence. (K, et al., 2022) Strategic use of sound can mould a specific atmosphere, where moments of silence dance with our perceptions, allowing for visualization. (Safrilia, et al., 2017)

- Reduction in stress is associated with the use of pleasant, natural, and calming music. (Karmele, et al., 2019)
- Longer reverberation times are generally perceived as less pleasing, while shorter reverberation times tend to generate more happiness. (MO, et al., 2015)
- Monosyllabic sounds within the frequency range of 110 Hz to 660 Hz hold a special allure for the human ear, evoking a sense of tranquillity.
- Sound sources can be categorized as; anthropogenic, faunal, mechanic, natural, (Ma & Thompson, 2015)
- **Olfaction**
- While olfaction may have a relatively smaller role in perception, it has a substantial influence in shaping the ambiance of a given environment. (Weber & Heuberger, 2008) This sense exerts the greatest influence on a room's memory. (Safrilia, et al., 2017)
- A prominent contributor to the sick building syndrome is the presence of unpleasant odours. (Spence, 2020B)
- The strategic incorporation of scents associated with specific places, functions, or atmospheres can lessen stress and foster an attraction to that area. (Spence, 2020B)
- The fragrances emitted by blooming plants in a natural setting can evoke both alertness and tranquillity, whereas synthetic scents are often perceived as intense and unpleasant. (Weber & Heuberger, 2008)
- The presence of unpleasant odours can nullify the positive influence of pleasant scents, regardless of the sequence in which they are introduced. (Weber & Heuberger, 2008)

Touch

"A building's handshake is the door handle" - Juhani Pallasmaa (Pallasmaa, 1996)

The haptic system engages with stimuli involving physical contact, untying the recognition of objects. Touch, often referred to as subconscious vision, imparts three-dimensional insights. (Safrilia, et al., 2017)

- Both, softness and roughness contribute to the pleasure we derive from tactile experiences. Soft touches, such as those from fur, silk, or velvet, are associated with pleasant feelings, while rough touches, like sandpaper, tend to evoke unpleasantness, fear, anger, and disgust. Additionally, friction plays a substantial role in our perception of a surface.
- The temperature of surface can even provide cues about the thickness of the material. (M. & Tiest, 2010)
- Moreover, the degree of control is greater in passive touch, where the surface moves over the observer's hands, over active touch, where the user moves their hands over the surface. Additionally, surfaces with greater density tend to provide a higher level of pleasure. (Sungsoo, 2021)

Sensory Design and its role in Architecture

The architectural framework of responsive architecture engages both occupants and the environment in influencing emotions, thoughts, and behaviour. This is where sensory design comes into play—a method that centers on constructing spaces with a consideration of their impact on individuals. This continuous interplay between our body, movements, reactions, and the spaces we inhabit creates a dynamic relationship, facilitating sensory experiences. (Safrilia, et al., 2017)

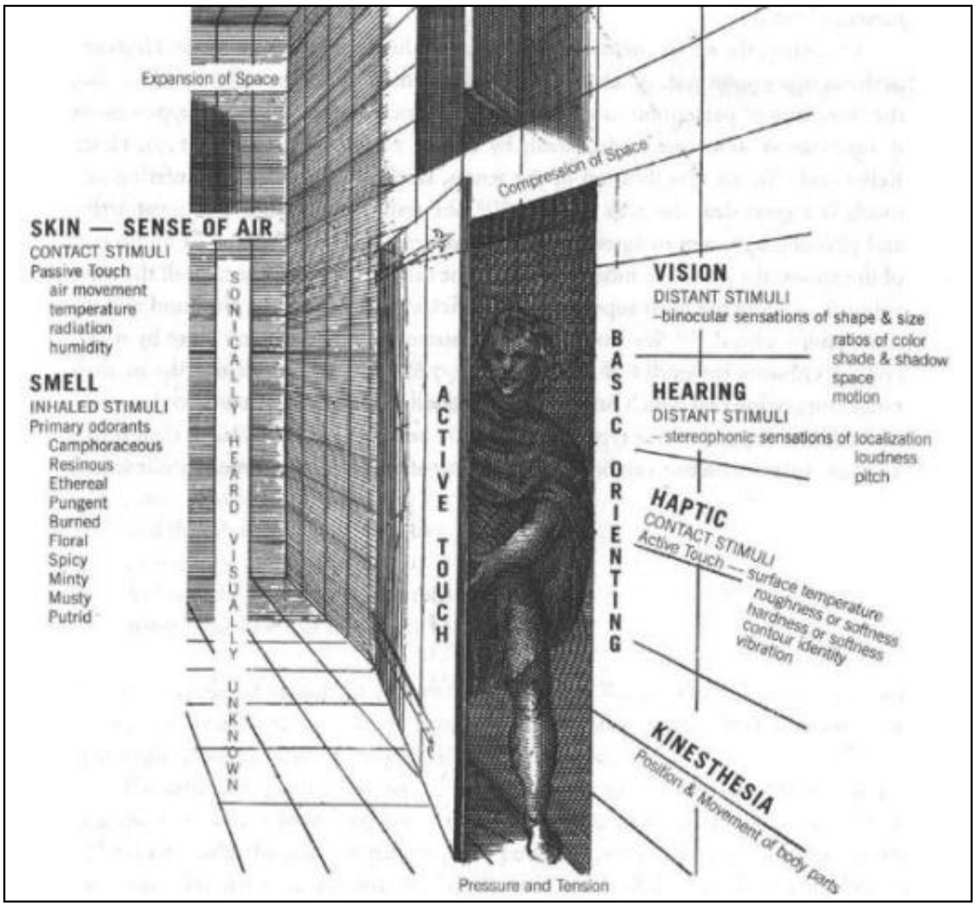

Figure 1:Ranges of the Senses in the Human Body

Perception and experiences

The perceptual and sensory systems work complementary mechanisms. Our perception of space also results from the subsequent interpretation and processing of this information. (Verbanic, 2010) These sensory and perceptual processes collectively shape our experiences when engaging with the different elements of sensory design. (Minter, n.d.)

Importance of integrating Sensory Design

Incorporating sensory design into architecture enhances the creation of interactive spaces, leading to improved human experiences. Such spaces not only enhance a building's functionality but also elevate the overall user experience. The utilization of sensory design is particularly advantageous in retail environments, as it raises brand awareness and boosts sales, underscoring its significance in space design. (Nicasio, 2018)

Different elements and parameters of Sensory Design

Key elements such as materials, landscaping, water, and the sky play a significant role in this approach, while parameters like light, scale, volume, texture, colour, gravity, and voids are crucial in shaping the sensory experience. These parameters exert influence over the intensity of the sensory encounter. The essence of sensory design lies in skilfully integrating these elements with the necessary parameters to create a space that offers a harmonious sensory experience. (Khan, 2019)

Case 1: Garden of Five Senses, Delhi, India

It is a large public recreational space in Delhi where people can come to relax. It is a space designed to stimulate one’s sensory response to the environment. (Abhinav Guppta, 2017)

Vision: It contains a wide range of colours, shapes, patterns, unique elements, and diverse features like flowers, plants, and trees, arranged in different combinations of colours and patterns.

Touch: Plants, with unique textures, textured bark of trees, various materials, natural elements, and even the gentle breeze enrich the tactile experience.

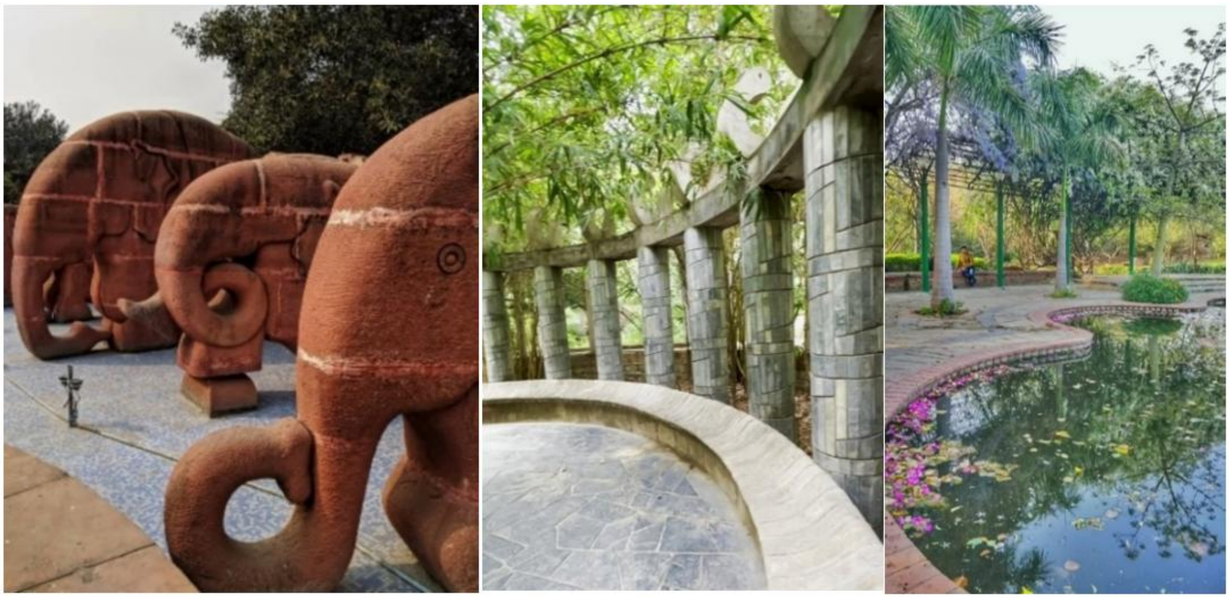

Figure 2:Sculptures, natural textures, and water bodies in the garden

Smell:

The garden has an array of delightful flowers, aromatic herbs, and trees like jasmine, violets, neem, tulsi, mint, that fill the air with fragrances.

Taste:

A lot of fruit trees and herbs like jamun, guava, neem, tulsi, mint, etc. which release fragrances which stimulate the taste buds.

Hearing:

The melodious chirps of birds, the soothing sound of flowing water, the rustling of grass, the sound of wind rotators, the textured path's footsteps, the subtle crunch of pebbles and gravel, together create a diverse auditory experience.

Case 2: Bruder Klaus Field Chapel, Germany

Designed by Peter Zumthor, this project serves as an exploration into how built forms, materials, and light influence sensory experiences. (Khodadadian, n.d.) Situated in the middle of fields, this chapel attracts people through its creation of a unique atmosphere. (Moody, 2019)

The primary focus of this project is the use of materials obtained from the surroundings and the active involvement of the client's friends and acquaintances in the construction process. (Khodadadian, n.d.)

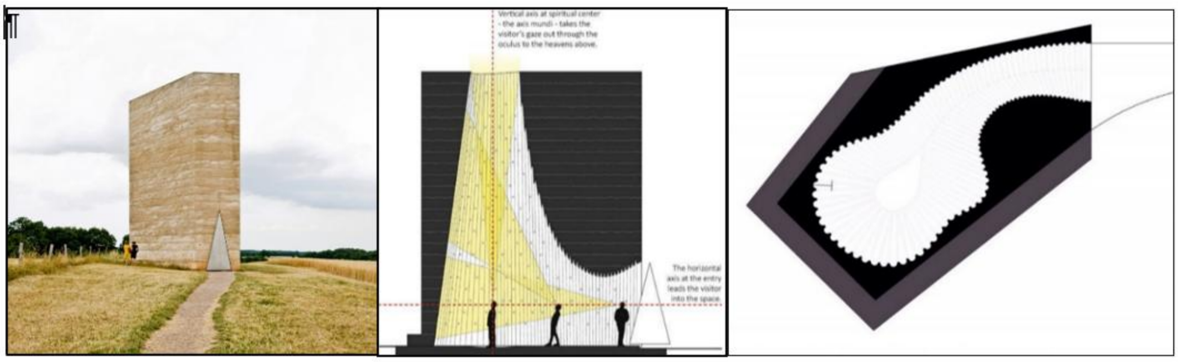

Figure 3 : Exterior view, Plan and Section of Bruder Kaus Field Chapel

Vision:

The stainless-steel entrance door's unusual shape and thickness, emphasizes the door's heaviness even before it is opened. The unexpected transformation from a rigid exterior to a sloping curvilinear interior, and textures creates a mystical experience.

The interior space features an oculus, serving as the source of light. Tiny beams of light through small holes covered with hand-blown glass, looking like stars.

The floor is coated with a molten mixture of lead and tin, and as rainwater drops from the oculus, it collects to form a reflective surface on the ground, capturing the interplay of light and inner surfaces.

Touch: The surfaces and patterns can be felt physically through different textures and shapes.

Smell: The interior's form and texture are shaped by the slow burning of tree trunks for three weeks after the concrete has set. The burnt fragrance of fire and ashes create a different olfactory experience within the space.

Taste: In the chapel, the persistent scent of fire and ashes provides a subtle burnt and smoky taste. Additionally, sitting outside, individuals experience the taste of corn due to the scent of corn from nearby fields.

Hearing: In the interior space, a wooden bench is surrounded by burning candles, creating an atmosphere of beautiful silence, encouraging meditation. Outside, there is a harmonious play of wind through the cornfields.

Case 3: Therme Vals Spa, Switzerland, Europe

The Therme Vals is an innovative combination of a thermal spa and hotel, constructed above the thermal springs in Switzerland designed by Peter Zumthor. (Anon., 2009)

This architectural masterpiece aims to rediscover the advantages of ancient bathing practices, focusing on the refreshing properties of natural thermal spring water. The design is centred around a rich sensory experience, achieved through the harmonious interplay of light and shadow, the integration of open and enclosed spaces, and the incorporation of linear features.

Figure 4 : Oculus; Texture, Light from the door opening & glass optics; Wooden trunks used as formwork

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This architectural masterpiece aims to rediscover the advantages of ancient bathing practices, focusing on the refreshing properties of natural thermal spring water. The design is centred around a rich sensory experience, achieved through the harmonious interplay of light and shadow, the integration of open and enclosed spaces, and the incorporation of linear features.

Vision: The native grasses are seamlessly extended in the visual landscape, offering breathtaking views of the surrounding landscape. An 8 cm gap between the slabs allows natural light to interact with the openings. Red lighting and red-stained concrete walls are implemented in hot water bathtubs creating a calming ambiance. In contrast, blue lighting is implemented in cold water baths.

Smell: Interlinked passages lead to distinct sensory encounters in each room. Stone, with its own subtle fragrance, releases a unique scent. Quartz stone smells like roughness and pureness. Upon leading to the "Flower Pool," one is immediately greeted by the refreshing sensation of moist air. The walls contain a variety of delightful smells.

Hearing: This environment brings out echoing sounds from the bubbling and flowing water. The warm mist in the air imparts a sense of quietness and calmness, establishing a comfortable zone. The dimly lit space heightens the other senses, making people absorb the soothing melodies of composer Fritz Hauser, echoing through the hidden speakers.

Touch: The sense of touch provides a diverse range of information, encompassing temperature, structure, abrasiveness, and softness simultaneously. Val's design strategy places significant emphasis on defining softness and hardness. Materials such as uniform concrete, polished terrazzo, and Valser Quartzite stone are used, imparting a natural texture to the environment.

Taste: At the Therme Vals, individuals can explore their taste amidst various temperature pools and mysterious spaces designed to engage their senses. These distinctive environments allow visitors to select the one that aligns with their taste preferences.

Materials and methods

Method(s) opted for Data/ case Selection

Initially data was from diverse sources such as research papers, books, and articles, on the topic. The derived inferences will include the background information and essential justifications necessary to establish the study's framework. The selected case studies aim to provide practical applications of sensory design, focusing on elements and parameters that contribute to an elevated experiential quality. Additionally, existing analyses and interviews supplement data collection for comprehensive conclusions.

Method(s) opted for Data Collection A survey from architectural professionals explored the significance of sensory experiences in the built environment and their views on using senses as design tools. The study involved 100-110 participants and utilized a questionnaire-based approach.

Method(s) opted for Data Analysis

Responses in the questionnaire, conducted among diverse architectural professionals, are analysed using pie charts to illustrate data along with percentages. The analysis, centered on Human Perception, relies on the Likert scale to ensure accurate rating of responses, enabling a clear understanding of perceptions.

Advantages and Limitations of the method(s) adopted

The selected method using Google Forms streamlines data collection, while a statistical approach enhances analysis. Using the Likert scale simplifies data gathering procedure. The responses from architectural professionals, provides valuable and clear insights into contemporary design approaches.

Figure 5 :Therme Vals Spa

RESULTS AND DISCUSSION

Comparative analysis of case studies

	Garden of five senses, Delhi	Bruder Klaus Field Chapel	Therme Vals Spa, Switzerland
Vision	-Variety of flowers, plants, and trees -Changing materials and patterns in the pathways -Various species of birds, butterflies, etc.	-Entrance door -Exterior & interior unexpected change -Lead and tin floor -Oculus & small holes -Beautiful lines, textures, color	-Building harmoniously follows the contours of the natural terrain -Series of consecutive wide openings with monolithic wall -Color usage
Touch	-Variety of plants, materials -temperature of the materials	-The textures and shapes of the materials	- Softness and hardness -Uniform concrete, polished terrazzo, Valser Quartzite stone
Smell	-Pleasant flowers, herbal plants, trees like jasmine, violets, neem, tulsi, mint, etc.	-Burnt fragrance of framework of tree trunks	-Stone, quartz -Flower pool
Taste	-Fruit trees and herbs like jamun, guava, neem, tulsi, mint, etc.	-smoky taste of fire & ashes -corn fields	-Various temperature pools and mysterious spaces
Hearing	-Chirping or whistling of various birds	-Beautiful silence -Play of wind in cornfields	-Echoing sounds of bubbling and flowing water -Hidden speakers

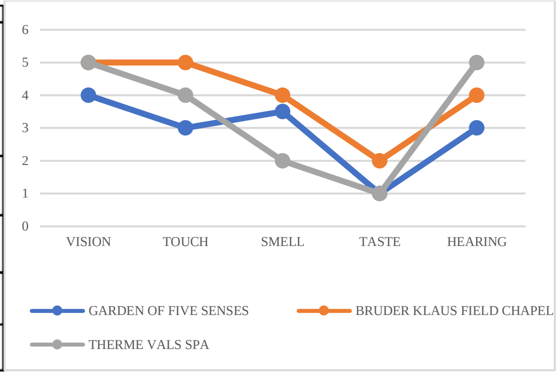

Figure 6 :Comparative analysis of case studies

Analysis of Survey Data

The study incorporates responses from 110 Architects from India- 54 females and 56 males.

- 97.2% of the architects believe that architecture has the potential to transform human behaviour and perception.
- 93.6% of them agree that built spaces should be designed with sensory design aspects to create an experience by impacting human senses.
- 86.2% architects consider the sensory design approach to enhance the experiential quality of a space while designing.
- Most architects believe that public spaces, museums, and art galleries have a requirement for experiential quality design.
- 94.% of them agree that this way of designing can help in better performance of humans in these spaces.
- 69.8% architects believe that architectural practices nowadays lack the aspect of creating multi-sensory experience & mainly focuses on visually pleasing environment.
- Most of them feel that the biggest challenge while implementing design that focuses on experiential quality is the lack of awareness of experiential design tool.

CONCLUSION

The paper aims to highlight the significance and influence of architecture & the built environment on individuals and their experiences.

As humans, we rely on our five primary senses to perceive and comprehend the world around us. They gather information from various stimuli, such as light, sound, spatial dimensions, proportions, flooring patterns, landscaping, and more as shown in Table 2.

Table 2:Senses and stimuli available

SENSES	TOUCH	OLFACTION	VISION	AUDATION	TASTE
Stimuli available	Air Movement	Pungent	Colour	Loudness	Landscape
	Temperature	Burnt	Shade	Echo	Shrubs
	Roughness	Floral	Shadow	Vibration	Herbs
	Softness	Spicy	Space	Lightness	Colours
	Vibration	Minty	Texture		Texture
		Musty	Temperature		
		resinous	Light		

This world is full of diverse experiences that evoke our senses as well as a range of feelings and emotions. Understanding the needs of users and clients is crucial for architects, enabling them to use spatial elements that elevate the overall experiential quality of a designed space. Architects are like a sculptor, shaping reality through elements such as light, voids, gravity, offering a unique opportunity to enhance these sensory experiences.

To explore sensory design in architecture, it is essential to draw inferences from various literature and case studies, exploring the roles, theories, and practices by different architects. Through the survey questions asked to architects, an understanding emerges regarding their perception towards designed spaces. The questionnaire is designed to show the deep impact of architecture on human behavior and perception, utilization of sensory design tools and architects' preferences for specific building types, tools and challenges associated with sensory design in architecture.

The study has revealed interesting facts, creating a way for the development of a design approach in harmony to human sensitivity. This design aims to cater to all parts of society, encouraging social inclusion by destroying barriers related to both, society, and disability.

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Urban transformation of Nashik City: Healthy streets and Built Environment

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Abstract— India's towns and cities struggle to maintain a happy and healthy community. The concept of Healthy Streets offers people around the world a result-based approach to creating sustainable and attractive urban spaces. The purpose of the Healthy Streets Approach is to create a city where people choose to walk, cycle, and take public transportation to create a more inclusive and healthier street environment. Nashik, a city of religious importance has tourist activities as the backbone of the economy. Nashik is suffering from a lack of street infrastructure needed to make its residents keen to walk. The study focuses on transforming the roads of Nashik into healthy streets for well-being. The study emphasizes the role of surroundings and built environment on the pedestrian & health behavior of residents. It also reveals the importance of public transport in traffic management. In the current scenario, the roads of Nashik city are not pedestrian-friendly. To overcome the concept of healthy streets needs to get implemented. The study proposed a three-year action plan for Nashik City in terms to make it livable and walking-friendly. This plan envisions a livable and pedestrian-friendly cityscape, focusing on diverse facets of transport infrastructure, including a public bicycle system, optimized parking solutions, and the integration of green landscapes. In this holistic approach, the study not only underscores the vital role of the built environment in shaping pedestrian behavior but also highlights the crucial role of public transport in effective traffic management.

Keywords: Healthy Streets, walkability, pedestrian, street infrastructure.

INTRODUCTION

Streets serve as more than just a means of transportation for cars through the bustling urban environment. These are the veins that pound with the activity of social interaction, commerce, and leisure. However, the concept of "healthy streets" sticks out as a sustained light that promotes community and general well-being in urban settings among the cacophony of urban dynamics. The streets play a crucial role in urban ecosystems by facilitating social cohesiveness and the unimpeded flow of people, goods, and ideas. Beyond just being useful, streets are vibrant public spaces that support social cohesion, cultural exchange, and economic activity. Streets, which city dwellers use for a multitude of reasons, represent the varied nature of urban life, from bustling marketplaces to serene boulevards. In essence, "healthy streets" refers to streets that prioritize people's health and well-being over conventional ideas of urban design. (Plowden , 2020) Healthy streets have features like green infrastructure, pedestrian-friendly design, and an emphasis on active transportation options including walking, bicycling, and public transportation. A healthy relationship between people and their built environment is facilitated by healthy streets, which aim to provide inclusive, accessible, and environmentally sustainable urban spaces.

The concept of "healthy streets" emerged from growing understanding of the damaging impacts urbanization has on public health and environmental quality. Influenced by groups such as the Healthy Cities Movement and New Urbanism, policymakers and urban planners began to view streets as fundamental components of living, healthy communities, rather than just as thoroughfares. The healthy street concept emerged as a comprehensive approach to urban planning, based on multidisciplinary research in public health, transportation, and urban design, with an emphasis on enhancing people's physical, mental, and social well-being. In an era of rapidly rising urbanization, population density, and environmental issues, the importance of healthy streets in urban design cannot be overstated. Because conventional street designs put the car above pedestrian services, they cause social isolation, air pollution, and sedentary lifestyles. (McIntosh, Marques, & Melody, 2021) Urban planning frameworks that incorporate healthy streets are becoming more and more important as communities strive to address disparities in public health and lessen the consequences of climate change.

The idea of a healthy street is important because it has the power to fundamentally transform urban environments into vibrant, hospitable, and sustainable spaces. Healthy streets, which promote natural spaces and active transportation while giving priority to the requirements of bicycles and pedestrians, can serve as a model for creating resilient, livable communities. Embracing healthy street principles aligns with global sustainability objectives, including the Sustainable Development Goals of the United Nations, indicating its relevance in addressing pressing urban concerns. Though the importance of healthy streets is increasingly being acknowledged, particularly in India, the design and implementation of such projects is still in its infancy. (Taccone, 2022) India's urbanization is characterized by a sharp rise in motorization, broad growth patterns, and a lack of funding for pedestrian-friendly infrastructure. Consequently, Indian cities face issues including air pollution, gridlock, and cramped public spaces that exacerbate health disparities and degrade urban quality of life.

This paper aims to highlight the significance of healthy streets in Indian cities, with a focus on proposing an action plan for healthy streets development for Nashik city in Maharashtra. The goal of the paper is to show how specific design interventions can lead to healthier and more sustainable urban environments by analyzing the distinctive urban dynamics of Nashik.

Study area and data collection

The city of Nashik, which lies in Maharashtra, India's northern region, is an example of how tradition and modernization can coexist. Situated on the serene banks of the sacred Godavari River, Nashik is an important part of India's cultural and historical fabric. Nashik captures the attention of tourists and locals equally with its dynamic metropolitan landscape and rich mythological legacy, providing a window into the essence of Maharashtra.

Nashik is regarded as one of the holiest cities in Hindu mythology and is associated with religious holiness and devotion. It is well-known for being one of the four locations for the Kumbh Mela, a revered journey that draws millions of devotees from all over the world. The city is home to several temples that are revered, including the well-known Trimbakeshwar and Kalaram Temples, which bring tourists looking for peace and enlightenment. Beyond its religious significance, Nashik is becoming a major tourist destination with a wealth of attractions like the peaceful Sula Vineyards and the gorgeous Dudhsagar Falls, giving it the title of "Wine Capital of India."

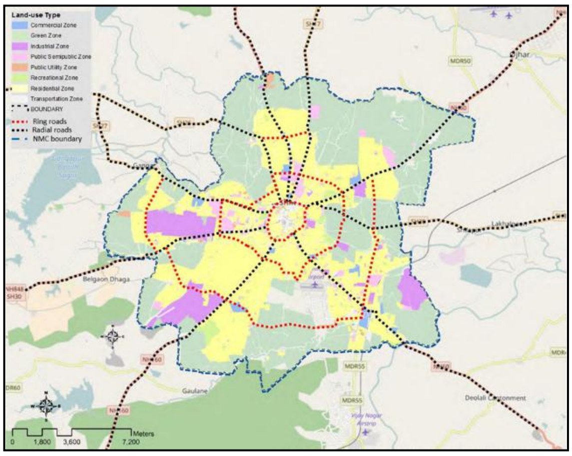

Figure 1 : Land use and Road Network in Nashik

Nashik is an area of about 267.48 square kilometers that includes both urban and rural areas, and it is spread out throughout the beautiful Maharashtra environment. Pulsating with the vivid energy of its diverse community, Nashik is the sixth largest city in Maharashtra, with over 2.2 million people living there. Major roads and intersections connect Nashik's urban infrastructure, providing vitality to its growing population. Several notable routes that enable easy access to nearby cities and areas are the Nashik-Aurangabad National Highway (NH-160), the Nashik-Pune National Highway (NH-50), and the Mumbai-Agra National Highway (NH-3). Crucial nodes in Nashik's transportation system, the Mumbai Naka, Dwarka Circle, and Mahatma Nagar Square, allow for the easy movement of both pedestrian and vehicular traffic.

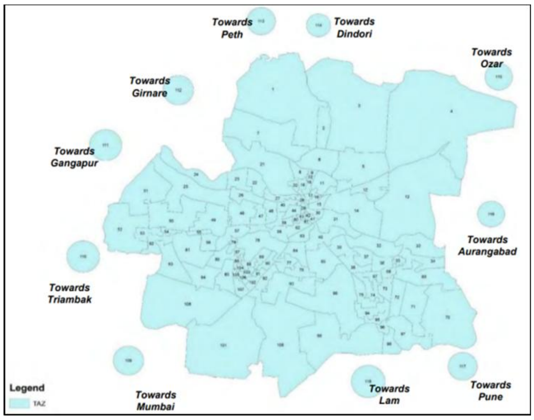

Figure 2 : Traffic Identified zones

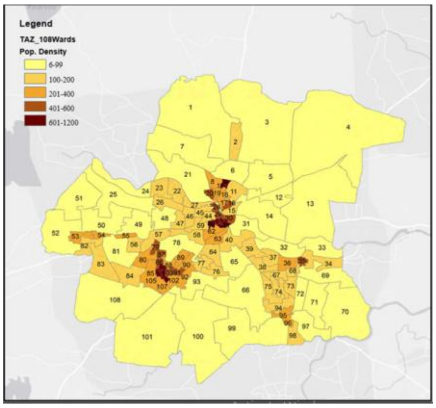

Figure 3 : Traffic Analysis Zones (TAZ) in Nashik

Nashik Municipal Corporation divides the city into 108 Traffic Analysis Zones (TAZs) based on ward demarcations. These zones serve as internal units for planning and implementing Healthy Streets initiatives, allowing for targeted interventions and localized improvements.

According to Urban Mass Transit Company, 68% of the population are considered choice riders, meaning they have access to at least one personal vehicle such as a Two-Wheeler or Car in Nashik. Conversely, 32% of the residents rely on private modes of transportation or public transport as they do not have their own vehicles. Also they have forecasted the travel demand for the horizon year 2036.

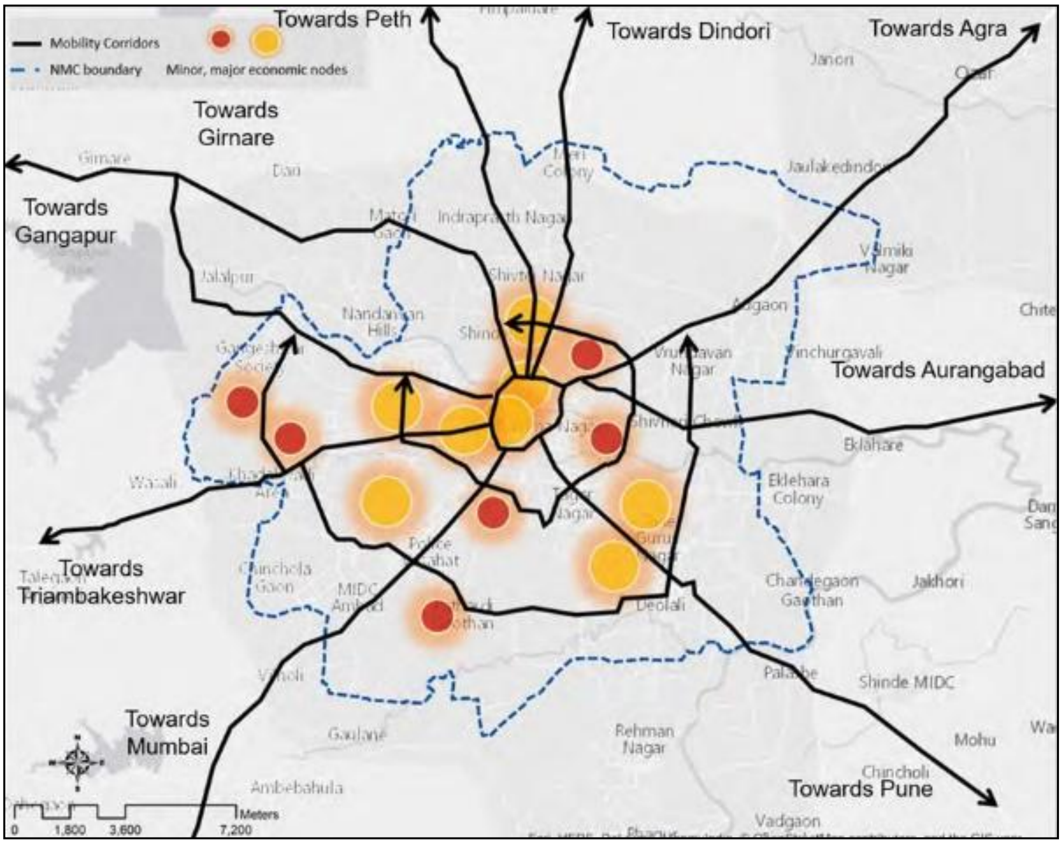

Figure 4 : Road Network Development vs Economic Nodes in The City

Year	2016		2036	
Mode	**Trips**	**% Share**	**Trips**	**% Share**
Walk	280319	15.8	681201	20.7
Car	105358	6	61452	1.9
2-Wheeler	745277	42.1	1011994	30.8
Auto Rickshaw	383291	21.7	64011	1.9
Public Transport	207376	11.7	1359670	41.4
Cycle	48484	2.7	109442	3.3
Total	1770105	100	3287770	100

Urban design concept proposal for action plan

As the nashik city continues to evolve and grow, there arises a pressing need to prioritize the health and well-being of its residents. In line with global trends promoting sustainable urban development, the design proposal outlines a comprehensive plan for implementing a Healthy Streets System in Nashik City. By reimagining its streetscapes as vibrant, inclusive spaces that prioritize pedestrian safety, encourage active mobility, and foster community engagement. The implementation of a Healthy Streets System will give a transformative opportunity for Nashik City to prioritize the health, well-being, and quality of life of its residents. Several crucial elements are addressed in this design proposal:

1. Pedestrianization of Key Areas: Identify select areas within Nashik City Center for pedestrianization, transforming them into vibrant pedestrian zones. This initiative will prioritize the safety and comfort of pedestrians, providing ample space for walking, seating, and socializing. By restricting vehicular access and enhancing streetscapes with greenery, public art installations, and street furniture, these pedestrian-friendly zones will serve as focal points for community engagement and leisure activities.

Figure 5 : Cycling Infrastructure Development

2. Cycling Infrastructure Development: Introduce dedicated cycling lanes along major thoroughfares and arterial roads, providing a safe and efficient mode of transportation for cyclists. Implement bicycle-sharing programs and install bike racks at key locations to encourage the adoption of cycling as a sustainable means of travel. Additionally, promote the integration of cycling infrastructure with public transit systems to facilitate seamless multimodal connectivity.

Figure 6 : Healthy Street

3. Green Streets Initiative: Launch a Green Streets Initiative aimed at enhancing the urban canopy and improving air quality within Nashik City. Plant trees along sidewalks, medians, and roadways to provide shade, reduce heat island effects, and mitigate air pollution. Incorporate green infrastructure elements such as rain gardens, bioswales, and permeable pavement to manage stormwater runoff and enhance ecological resilience.

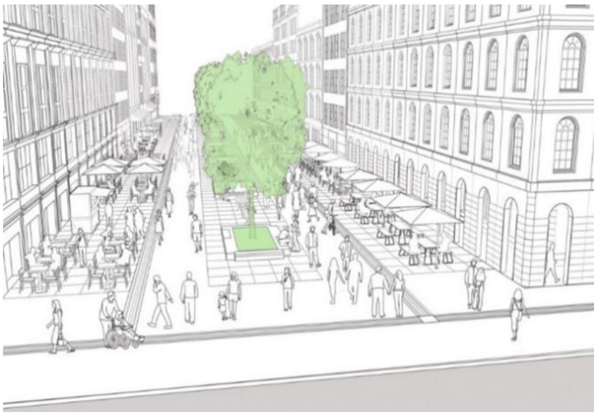

Figure 7 ; Streets for all

4. Streets for all: Adopt "streets for all" concept to ensure that streets are designed and maintained to accommodate the needs of all users, including pedestrians, cyclists, and motorists. Implement traffic calming measures such as raised crosswalks, speed humps, and chicanes to reduce vehicle speeds and enhance pedestrian safety. Prioritize universal accessibility by incorporating tactile paving, curb ramps, and audible signals at intersections.

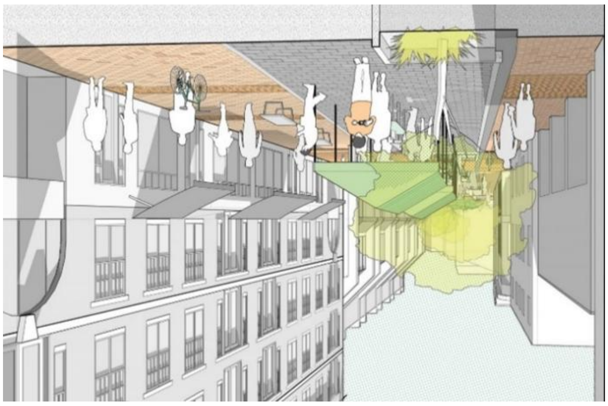

Figure 8 : Streets for all

5. Community Engagement and Stakeholder Collaboration: Engage residents, local businesses, and community organizations in the planning and implementation of the Healthy Streets System. Foster a sense of ownership and pride among stakeholders by providing them the streets as a community recreational space where people can interact, enjoy and live the social fabric of neighborhood.

Proposed road section

To facilitate the development of healthy streets, distinct road sections have been delineated to accommodate varying road widths. This strategic approach allows for tailored planning and implementation based on the specific characteristics and dimensions of each road.

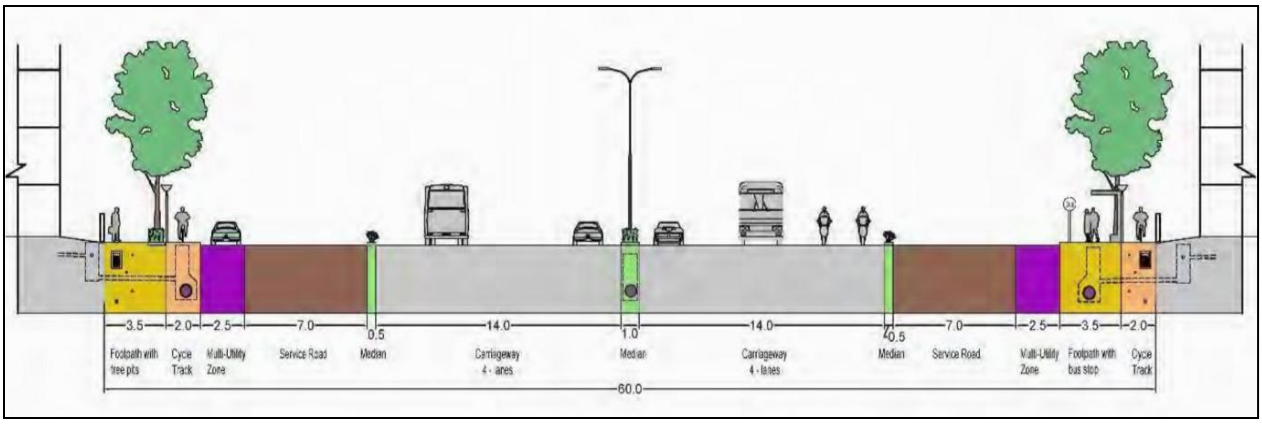

Figure 9 : 60m Row section

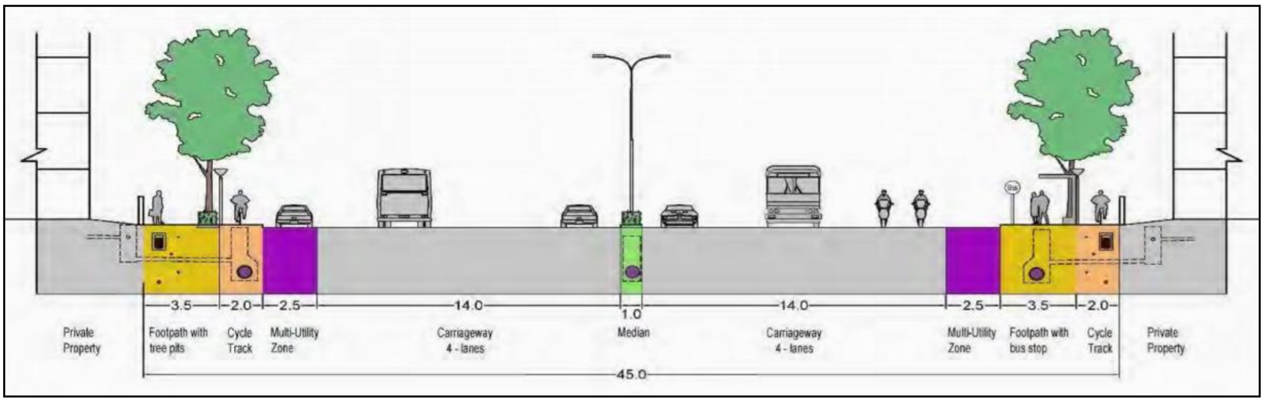

Figure 10 : 45m Row section

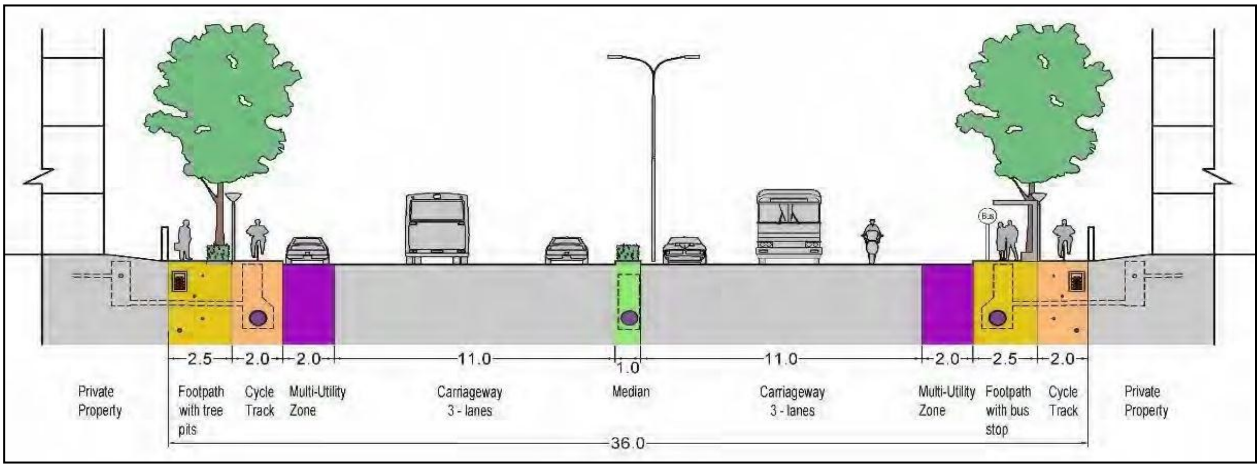

Figure 11 : 36m Row section

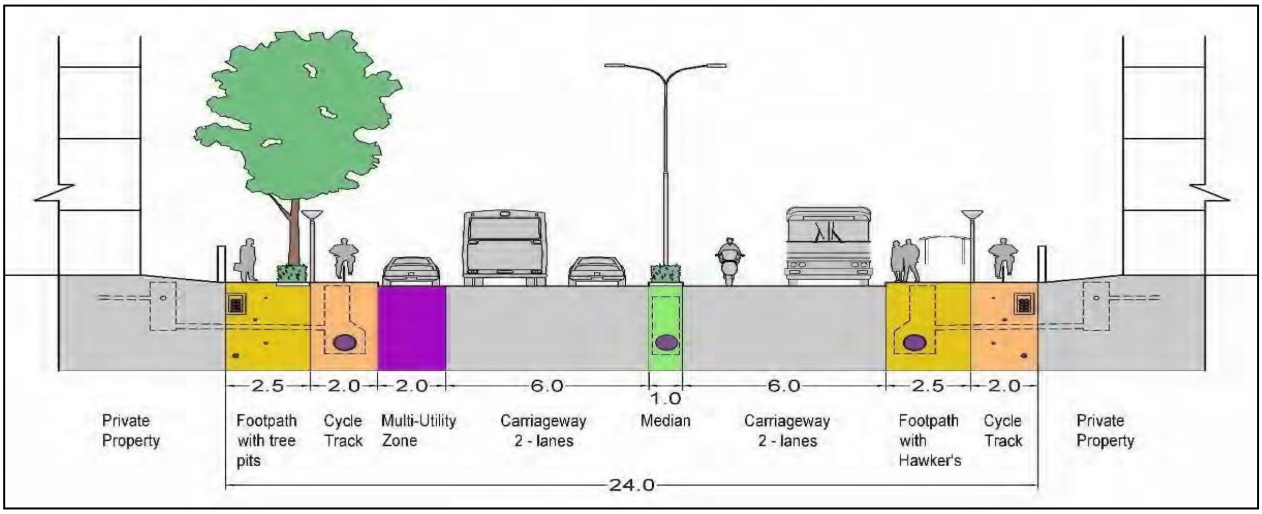

Figure 12 : 24m Row section

Network planning and phasing

The 3-year Healthy Streets Action Plan is a step towards committing and ensuring this long-term transformation, by laying down a roadmap. In the process of selecting roads to be incorporated into the Healthy Street network, a thorough baseline mapping of potential routes was conducted, considering various crucial parameters.

Existing walking and cycling infrastructure

Accident prone locations

Routes frequented by the cyclists and pedestrians.

Routes suggested by citizens or other stakeholders.

City-level destinations – transit stations, schools, markets, job centres, parks.

Collector streets that connect to major public transport, shared auto corridors.

Following an on-site survey, three specific routes have been chosen to be part of the Healthy Street network. This careful selection process ensures that the chosen routes not only enhance walking and cycling infrastructure but also address safety concerns, align with community preferences, and strategically connect key city destinations and transportation hubs.

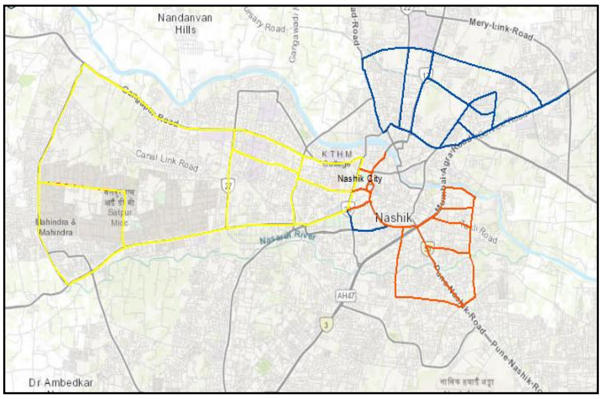

Figure 13 : Phase Diagram

The implementation of this action plan is structured as a three-phase program, with the goal of completing the entire project within three years.

Phase 1 route network: (Gangapur Road - CBS Road - Sharanpur Link Road - College Road)

Table 1 Phase 01Route Details

S.No	Name	Stretch	Length (km)	Road Width
1	Gangapur Road	Ashok Stambh to Garden Phata	7.65	30m
2	CBS Road	Ashok Stambh to Trimbak Naka	1.2	30m
3	Sharanpur Link Road	Godavari Bank Circle to Trimbakeshwar Road	2	24m
4	College Road	Old CBS to College road	3.1	18m
5	Mahatma Nagar Road	Jehan circle to ABB	2	30m
6	Trimbak- Nashik Road	Trimbak Naka to Amrut Circle	7.35	45m
7	Gangapur Satpur Link Road	Garden Phata to Amrut Circle	5.40	30m
8	Satpur Colony Road	Kan Naka to Mahindra Circle	1.82	18m-24m
Total			**30.52 km**	

The phase 1 route establishes vital connections between diverse areas, including a medium-density residential zone, an educational institute, neighborhood societies, and government offices. Notably, it provides seamless access to the core area of the city. The route strategically encompasses all academic blocks and libraries situated along Gangapur Road and Trimbak Road, ensuring convenient and efficient accessibility for students.

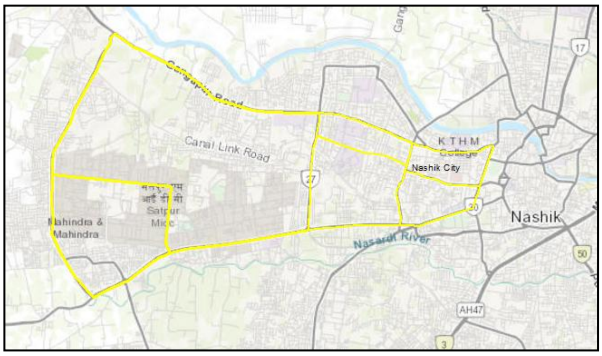

Figure 14 : Phase 01

Phase 2 route network: (Wadala-Ashok Marg - Nashik-Pune Road - Tapovan Link Road)

The designated route establishes crucial links between various areas, including both residential and commercial zones, areas with high population density, bustling pedestrian activities, and government offices. Providing convenient access to the core area of the city, it is structured into two parts:

Part 1 focuses on Arterial streets, Sub Arterial roads, and Collector streets, strategically connected to major public transport and Integrated Public Transport (IPT) hubs. This section ensures comprehensive coverage of key transportation nodes.

Part 2 extends to cover vibrant markets, shopping areas, and the internal roads of Shalimar. This layout facilitates easy accessibility for the community, particularly along Pune Road, enhancing the overall connectivity and convenience for the public.

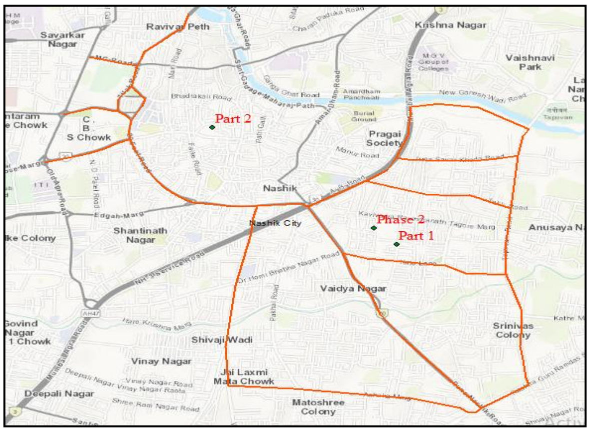

Figure 15 : Phase 02

Phase 3 route network: (Panchawati road - Makhamalabad Road - Dr. Dharmadikari Road - Peth Road - Dindori Road)

This chosen route establishes crucial connections among various areas, including a low-density residential zone, the Gaothan Area, and provides convenient access to the core area of the city. Particularly noteworthy is its comprehensive coverage of academic blocks and libraries along MERI (Maharashtra Engineering & Research Institutes) and Makhamalabad Road, ensuring easy access for students and surrounding residents.

The incorporation of cycle tracks along this route holds significant advantages for nearby residents due to the area's limited development infrastructure and lower population density. This thoughtful addition enhances the overall accessibility and promotes sustainable transportation options, aligning with the unique characteristics of the surrounding environment.

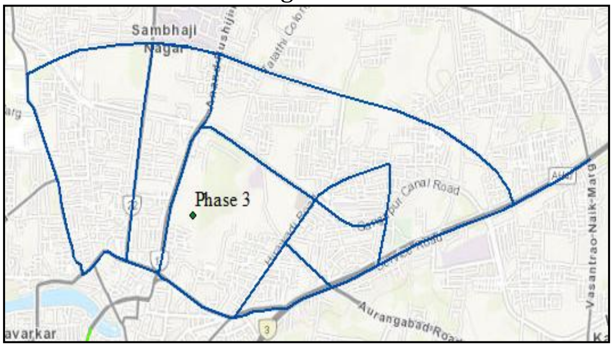

Figure 16: Phase 03

Table 2 Phase 02 Route Details

S.No		Stretch	Length (km)	Road Width
1		Ashok Stambh to Garden Phata	7.65	30m
2		Ashok Stambh to Trimbak Naka	1.2	30m
3		Godavari Bank Circle to Trimbakeshwar Road	2	24m
4		Old CBS to College road	3.1	18m
5		Jehan circle to ABB	2	30m
6		Trimbak Naka to Amrut Circle	7.35	45m
7	Gangapur Satpur Link Road	Garden Phata to Amrut Circle	5.40	30m
8	Satpur Colony Road	Kan Naka to Mahindra Circle	1.82	18m-24m
Total			**30.52 km**	

Table 3 Phase 03 Route Details

S.No	Name	Stretch	Length (km)	Road Width
Dwarka Area (Part 1)				
1	Wadala-Ashok Marg	Wadala Naka to Nashik Outer Ringroad Signal	3.1	30m
2	Nashik-Pune Road	Dwarka Circle to Nashik Outer Ringroad Signal	2.5	45m
3	Tapovan Link Road	Tapovan link Road	2.5	30m
4	Internal Roads	Takli Road, Kathe Lane, etc	4.2	18m
Shalimar Area (Part 2)				
6	Internal roads	Rk Junction to Shalimar Junction, CBS to Shalimar, etc	4.65	18m
Total			**16.5 km**	

CONCLUSION

The proposed Healthy Streets Action Plan for Nashik City represents a transformative approach to urban planning that prioritizes the well-being of its residents. By addressing the unique dynamics of Nashik and integrating key elements such as pedestrianization, cycling infrastructure, green initiatives, and community engagement, the plan seeks to create vibrant, inclusive, and sustainable urban environments. The phased implementation over three years demonstrates a commitment to long-term transformation, considering factors like existing infrastructure, safety concerns, and community preferences. As Nashik grapples with the challenges of rapid urbanization and associated issues such as air pollution and traffic congestion, the adoption of healthy streets principles becomes imperative. This comprehensive plan not only aligns with global sustainability goals but also presents a template for other Indian cities facing similar urbanization challenges. By embracing the Healthy Streets concept, Nashik has the potential to redefine its urban landscape, promoting not only physical health but also social cohesion and environmental sustainability.

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Biophilic Design Approach in Regenerating the Socio-Cultural Well-Being of Delhi NCR

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Abstract—The paper aims to study the socio-cultural stratification of the Delhi NCR region and the implication of biophilic designs. The detrimental effects of pollution have led to compromised air quality, warranting a re-evaluation of design methods. The design professionals, should explore an approach that infuses design with natural elements, creating a transformative environment promoting physical and mental health. Focusing on integrated approach into existing framework and augmenting the impact. It is a strategic approach to study nature and indigenous skills to create a built-in environment for the cosmopolitan doctrine that resonates with the cultural identity of the Delhi NCR region. In this viewpoint, the paper discusses opportunities for combining integrated spaces with biophilic interventions, like light therapy and non-pharmacological practices, to create a sustainable and culturally resonant space for sowing mental and physical health. The study intricately weaves the elements of various regions, inherited from the diverse art forms and living styles of the people who have migrated from various parts of the country to Delhi NCR region. Through in-depth analysis of users' perspectives and case studies, the research aims to provide a comprehensive overview onto shedding lights and adding nature to design in fostering self-care. The unearthed transformative approach seeks to foster nature in the modern building dwelling. Adding these modalities can also improve depressive symptoms and can add a therapeutic interior environment solution to the users. Following the principles of salutogenesis and amalgamating the biophilic interior design practices, the research has helped provide a few approachable solutions to regenerate socio-cultural well-being. To put the best foot forward, the effort has been put in not only to work towards the well-being, both mental and physical, of the residents but also to build an aesthetic tapestry which has direct and indirect resonance with, by and for nature, to strike sustainability with energy-efficient solutions. After entering this era of post-COVID-19, when people are aware that in-house sanity and the built environment is of utmost importance, biophilic interventions in interior practices have become a boon.

Keywords: Strategic approach; cosmopolitan doctrine; biophilic intervention; non-pharmacological practices; therapeutic interior environment; salutogenesis

INTRODUCTION

The study addresses the bleeding caused by rising air pollution levels in Delhi-NCR. Though residents have developed endurance against the rising pollution level, the conditions have unsympathetically affected the way of life in Delhi-NCR. The physical and mental health of communities in these areas has been affected adversely. The situation has posted an urgent need for all the government and private bodies to take the required measures to curb the rising environmental toxicity. This paper is an effort as design professionals, serving professional and social responsibility, to combine design thinking with system thinking to chart a holistic approach towards rebuilding the notion of well-being in society. The theory of biophilia has a cascading effect on the socio-cultural fabric of the city.

To understand the problems that have led to many health hazards, it's imperative to highlight the rising pollution levels in Delhi–NCR statistically; a few references of the AQI levels of Delhi from 2016-2021 are shown below.

Good Days	17
Moderate Days	374
Unhealthy for Sensitive Group Days	404
Unhealthy Days	826
Very Unhealthy Days	350
Hazardous Days	153

DAILY AIR QUALITY INDEX DELHI 2016-21

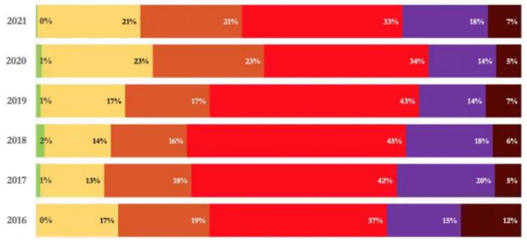

Figure 1 : Air Quality Index; AQI of Delhi and NCR ,(Smart Air, a social enterprise and certified B-Corp)

As per an article in India Today published on 7th November 2023,(Today, 2023), The national capital's Air Quality Index (AQI) stood at 394, a marginal improvement from 421 recorded at 4 p.m. Despite a marginal dip, the concentration of PM2.5 – delicate particulate matter capable of penetrating deep into the respiratory system to cause illnesses like asthma and cancer and triggering other health problems – exceeded the government-prescribed safe limit of 60 micrograms per cubic meter by seven to eight times in the capital. Several cities in neighboring areas have also reported hazardous air quality; Ghaziabad recorded an AQI of 338, Gurugram 364, Noida 348, Greater Noida 439, and Faridabad 382. As the data shows that pollution is dipping to hazardous levels year by year, it has become imperative that modern dwelling units adopt transformative approaches which are functional, aesthetically pleasing and resonate with nature to boost the health of inmates, which in turn ensures the social and cultural well-being of the community.

Further pondering over the question, what keeps people socially and culturally well? The stepping stone started with comprehending salutogenic studies (Mittelmark & Bauer, 2017), which focused on the origin of health and the factors that support human health and well-being rather than on factors that cause diseases. These studies have revealed that various non-pharmacological practices like light therapy, meditation, exercising, lifestyle changes and specific biophilic interventions in the built-up habitat can raise the bar. As designers, this paper focuses on biophilic interventions in interior design practices that can give way to the therapeutic interactive environment that curbs air pollution passively. The biophilia hypothesis can be defined as the fundamental connection of humans with nature and life-like process, asserts physical, mental and emotional well-being; for example, recent studies have shown that even minimal connection with nature, such as looking at it through a window, also increases productivity and health at any built-up habitat of humankind. (Peter H. Kahn, 1997).

Adaptation of Biophilia in Delhi-NCR

The theory of biophilia was introduced in 1984 by sociobiologist Edward O. Wilson in his book (O.Wilson, 1984,2003), where he defined that Biophilia is the tendency to focus on life and life-like processes around us. He advocated that the natural environment can work miraculously on holistic well-being and efficiency. Later, Kellert coined the term biophilic designs. Biophilia is a feeling of oneness with biodiversity, an emotional affiliation with other living organisms. Though humans have developed a built environment, there is still an innate need for nature to connect with the human world. (Kellert, 1993). It is no secert that human-centred benefits are reaped by two key factors: developing a connection with the surrounding natural environment and the culture and ecology of the places people live and work. (Gullikson, 2010;Kellert S. H., 2009).

By observing and discussing the user's perspective, a few challenges have to be highlighted before augmenting the suggestions that can help in coherent design solutions.Adaptation of biophilic design has a few implications in Delhi and the NCR region of the country:

- The capital's cosmopolitan doctrine has been developed with migrants from different states and cities of India, who carry a wide diversity in culture and lifestyle. Suggesting a therapeutic solution that can strike a chord with the interior spaces' finishes, functionality and aesthetics becomes challenging. An occupant who hails from south India is acclimatised to entirely different tapestry compared to a migrant in Delhi NCR from Northeastern states of India. The second challenge in initiating the use of biophilic measures is that there are very few options available in the market for green materials, and even if there are, people are not aware of where to procure this material. For e.g., bamboo laminates are not being constructed by all the leading companies in this Industry; only quite a fewlike Century Plywood and Merino, are offering this segment,

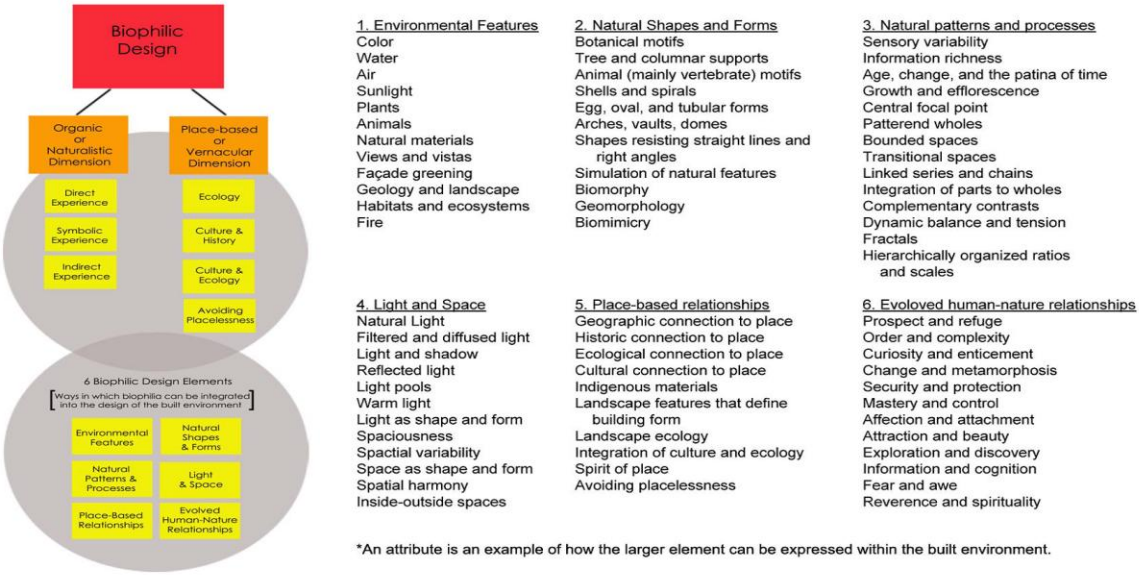

Figure 2: The Two Main Dimensions and Six Main Elements of Biophilc Design with Their Attributes, (Gullikson, 2010) (Kellert S. H., 2009)

- The second challenge in initiating the use of biophilic measures is that there are very few options available in the market for green materials, and even if there are, people are not aware of where to procure this material. For e.g., bamboo laminates are not being constructed by all the leading companies in this Industry; only quite a fewlike Century Plywood and Merino, are offering this segment,
- No government intervention to control the rates of green material. Conventional materials are abundant in the market at very cost-effective rates compared to green materials.For example, Zero-VOC (volatile organic compound) products are often more expensive than conventional paints.
- In the present situation, the landscape of cities has turned into a concrete jungle due to the drastic increase in the population of Delhi and the NCR region. This has also multiplied the complications of adapting regenerative measures of biophilic designs.
- There is a lack of promotion and awareness campaigns to the end users justifying the impact of using finishes with toxic components over biophilic substitutes in material and methods. There is hardly any propagation of how the mindless use of synthetic and chemical finishes
- in the interior space ruins the internal air of the built environment.
- Lastly, generating awareness and advocating the advantages of different linguistic communities with an average literacy level has made realising these nature-centric solutions even more challenging .

After evaluating all the above challenges, few biophilic design interventions has been suggested to develop coherent designs which primarily exuberate a sense of wellness while doing one's daily chores in the Delhi–NCR region.The approach helps in mitigating the level of pollution in the air, which is one of the prime reasons for respiratory health hazards and causes mental depression as people have to stay indoors as captives. Following the basic two tangents of biophilic intervention, organic or vernacular dimensions,a few suggestions have been proposed in this paper. The kellert's hypothesis of direct and indirect affinity of built environment and nature, and its six main elements with their attributes have been elaborated in the figure 2.

Biophilic Intervention can be carried out by incorporating all the above attributes, which are practical examples of integrating nature with the buildings directly,indirectly and symbolically. A solution as simple as opening windows in a direction inviting maximum sunlight in a room can be considered while any construction is being done. Direct connection to natural resources like sunlight helps sanitise the space and has a positive psychological effect. Vernacular biophilia can offer spirit to the place by adapting the elements and art-craft forms that connects with the cultural framework of the migrated inhabitants of Delhi-NCR. Vernacular biophiliaexuberates great comfort and avoid any feeling of placelessness,thus ensuring mental peace and socio-cultural well being of the migrants.

LITERATURE REVIEW

Identification of Gaps

Diverse methods were adopted, and literature study was done to identify the gap, which will help analyze the implications of applying biophilic solutions in Delhi NCR's urban frame. Ever since the theory of Biophilia' was introduced by Wilson in 1984, western countries have embarked on the journey of sustainability and have already marked their footprints on building a biophilic environment, which is a subset process of attaining sustainability. In the past, many intellects like Kellert have broadened the awareness of biophilic intervention in the built environments worldwide. India is still trailing behind due to the lost roots of "Prakirtik life style" which pre-existed in India since Vedic times, the deepened socio-cultural gaps and other complexities as discussed above.

"When nature inspires our architecture not just how it looks but how buildings and communities' function, we will have made great strides as a society. Biophilic Design provides us with tremendous insight into the 'why,' then builds us a road map for what is sure to be the next great design journey."-Rick Fedrizzi, President, CEO and Founding Chairman, U.S. Green Building Council (Kellert S. H., 2009)

Case Studies-Global Context

A comparative analysis of case studies was followed to manifest the application of green solutions and how to strike a delicate balance by biophilic interventions in a built environment of the Delhi NCR region. The case studies of a few global iconic buildings were analysed to comprehend the actual implications.

Biophilia was evident in the "Hanging Gardens of Babylon" (Dalley, 2013), an organic form of architecture by Antoni Gaudi of "Casa Batllo", which was inspired by the aquatic world (Kurnalı & Baş, 2022). Le Corbusier's "Immeubles-villas" of France was conceptualized in the early twentieth century in response to high-density urban living had an inner courtyard/garden (Meriläinen, 2014) and Frank Lloyd Wright's "Falling Water" (Fazzare, 2023). The construction was embedded without interrupting the geometry of nature. Designed in 1935, the renowned architecture was designated as a UNESCO World Heritage Site in 2019. In the past, these iconic buildings were constructed to romanticize nature. On studying these celebrated buildings, few gaps were identified in adapting the features in Delhi NCR.

a. To highlight from the "Babylonian Hanging Garden", present-day Iraq, the irrigation facility at various levels of terraces which must have been used in Babylonian hanging gardens is unclear. Currently, the site is nothing but a mound of bricks and mud. Only few hypothetical theories and images were identified.

b. The aquatic building in Spain, Casa Batllo by Antoni Gaudi, is a piece of art; here**, biomimicry has been adapted to connect built space with life processes and nature** in its surroundings. The limitation is that recreating any such structure would be overtly expensive and time-consuming in the present-day context. Moreover, Delhi NCR is meant to serve the masses; adopting biomimicry for the region would be impractical.

c. Le Corbusier's Immeubles-villas of France catered to the requirement of biophilic design for high-density buildings, which could have been adopted. Still, as per the study (Meriläinen, 2014), it is ambiguous whether such a building was ever realized or only conceptualized on paper.

d. FrankLloyd Wright's Falling Water is a true example of biophilic design with the kind of landscape offered by the mountains of Southwestern Pennsylvania . In context to Delhi NCR, many features of this milestone building cannot be realized owing to the topographical features of Delhi and their limitations.

After researching and analysing the iconic biophilic buildings from the pages of history. To exemplify the recent global approach of reconciling green infrastructure in the urban definition of cities using biophilia, a few more case studies were analysed from the last decade. The new paradigm of converting grey infrastructure to green infrastructure by complementing biophilic urbanism has emerged.

The approach practically means that greenery can also be integrated into and over built structures, not only in unconstructed areas. Some examples include integrated green walls and roofs that can create a biophilic façade for a building. (Giles Thomson, 2021). This thought justifies the construction of compact high-rise cities versus widespread ecological cities. **One Central Park (OCP), Sydney**, was briefly analyzed to understand the relationship between biophilia and its impact on the users.

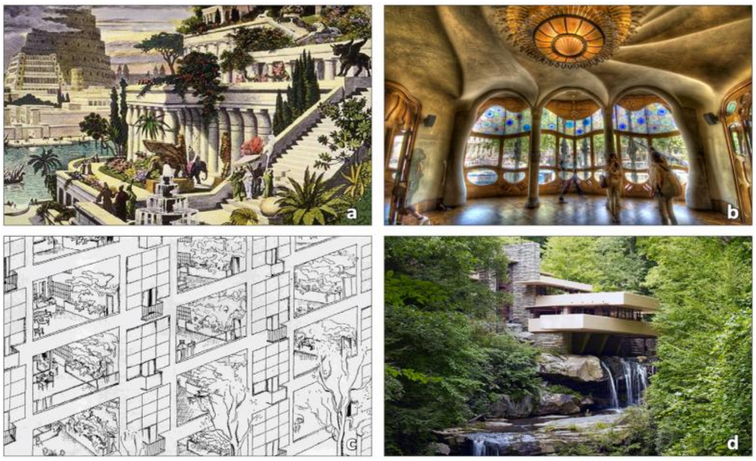

Figure 3: Examples of the integration of plants, water or analogous natural forms in architecture (a) Hanging Garden of Babylon (b) Antoni Gaudi's Casa Batllo; (c) Le Corbusier's Immeubles-villas; (d) Frank Lloyd Wright's Falling water, (Weijie, Torsten, & Julie

One Central Park (OCP), Sydney, completed in January 2014, has transformed environmental commitments into a visible architectural marvel by incorporating energy and power-efficient practices that follow a black water treatment plant, an alluring green façade and a cantilevered sky garden that has been cultivated by using a hydroponic system. Hydroponics is a system that allows plantations to grow on shallow slab-ledge and thin vertical green walls without soil. With the conservative use of water, irrigation is done with recycled water. The heliostats on the rooftop and cantilevered heliostat reflectors make it possible to bring a programmable amount of sunlight and heat in shaded areas to propagate vegetation. This urban structure adds a soothing biophilia that integrates green infrastructure in a mid of dense grey concrete

Jungle. These add-on factors accredited five-star rating for the structure by the Green Building Council of Australia (GBCA) (Berkel, 2014). It's a great example of genuine dialogue between nature and the built environment, little such adaptation has been witnessed in the Indian context.

Figure 4:'One Central Park' Sydney, Australia: Biophilic façade, (Berkel, 2014),(Giles Thomson, 2021)(Flamer, 2014)

Case Studies-Indian Context

Terminal 2 at Kempegowda International Airport, KIA, Bengaluru, inaugurated in the year 2023, is a unique example of the biophilic built environment that showcases the beauty of nature and the culture of Karnataka. It has been identified as the largest terminal in the world to be pre-certified with a Platinum LEED rating by USGBC (US Green Building Council). The airport has a built-up area of 255,645 square meters, reflecting the soul of Bengaluru, the City of Gardens. It has been designed and developed to give an immersive experience of unique flora and build a direct connection with the cultural and ecological habitat of Bengaluru. Terminal 2 art programme and installations are inspired by Bharata's Navarasa, as mentioned in the Natyashastra (Science of Indian dance forms), to resonate with thecultural diversity of south India. All six biophilic elements, as explained by Kellert, have been meticulously woven with the functional requirements of an airport in this project.

To further elaborate the details, connecting corridors have 10,235 square meters of green walls around the terminal, hanging gardens that cascade down from the terminal roof on the bronze veils and bells suspended from the ceiling and the green lagoons within the premises to the extensive forest belt area the terminal and boarding piers offer a return of many migratory birds and species.As per the study, it was a great challenge to hang such large installations and then rinse the plants without compromising the safety and convenience of the 24X7 service building thronged by passengers. To resolve such implications, Kempegowda International Airport(KIA) adopted a weather-based innovative irrigation system; this climate-smart micro irrigation system irrigates plants on a sensor-based automated system that runs on weather station information which records five parameters and provides the daily evapotranspiration per zone to set the irrigation cycle. This airport has raised the bar on designing healthier, more bio-diverse, culturally relevant and relaxing airports for tired travelers. (Desai, 2023).

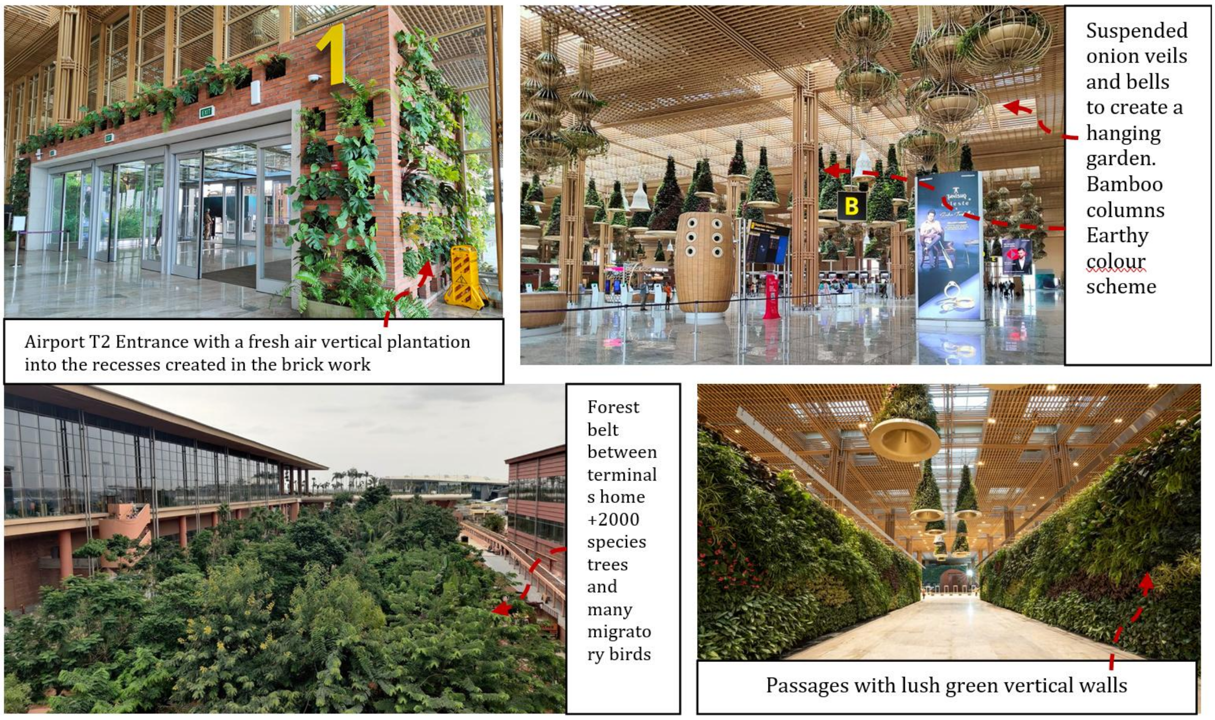

Figure 5: Images of Terminal 2 at Kempegowda International Airport, Bengaluru , (Desai, 2023)

b. An independent house, Ashvattha, People Tree House by Archaeopteryx, was explored and analysed for its biophilic attributes. It was an imperative site as it is located in the heart of the busy city of Delhi NCR- Noida. The 'People Tree House' belongs to a medical entrepreneur, a six-floor building with a basement to house a clinic and residential units at various levels. It is a 7000 sqft building constructed in full conversation with nature and adapts the principles of energy conservation and sustainability. (Abdel, 2022). Large openings in the south capture the sanitising sunlight and breezing air circulation, quadrant apertures, skylights, and cut-outs. The building generates energy, recycles, and irrigates to nurture life. With curved roofs and sloping skylights, rainwater is harvested in a storage tank; it's an ancient way of collecting water. This resource irrigates the plants at lower levels via a drip irrigation system. The house was constructed with the concept of 'collect-irrigate-store-re-use'.

It provides a visual respite by nurturing plants at various levels and complementing an earthy colour palette by incorporating Indian white marble and yellow sandstone on the floor and exterior façade. The building is connected with nature, form, function and human life process. Analysing the Indian buildings, i.e. Terminal 2 at Kempegowda International Airport, Bengaluru and an independent house, Ashvattha, People Tree House, gave an assurance that India has embarked on the journey of a healthier ecosystem. With AQI levels shooting from poor to toxic in the last decades, complementing the built environment with biophilia offers a cohesive solution that creates a passive wall of defence against pollution and incorporates aesthetics in the grey infrastructure. Designers and architects should adopt biophilic practices extensively to exuberate the feeling of wellness among inmates. Delightful spaces ensure the sense of being in a haven.

COVID-19 pandemic caught us unarmed , the world swept away, humanity became vulnerable, and it resulted in a global lockdown .The phase tutored the essence of reconnecting with nature in interiors and made us accept the prudence of salutogenic practices, of which biophilia is a subset.

Recommended solutions - Methods and Material

Going through the pages of history, the Indian subcontinent was in an absolute dialogue with nature. As India embarked to future, it gradually turned aloof from the green conversation in haste to adopt Western concepts. Before the day of reckoning, it is imperative to revive communication with nature, where flora and fauna were an innate part known for their medicinal and therapeutic values. We are bound to return to our roots to curb the current issues of increasing pollution levels and control global warming. Earlier, in the Indian subcontinent, temperature spikes and pollution hikes were resolved through a simple measures like tree walls around habitats, mud paste finishes on walls and flooring, vegetable dyes for the introduction of colours in wall paints and motifs representing nature, recycling of resources which avoided human carbon footprints on earth and rainwater use to seep back into the heart of mother nature. India was revered for its social and cultural well-being. People used to follow a lifestyle aligned with sun rise and sun set, which was known as the **'Satvik lifestyle'**, living in the sea of consciousness called **'Prakriti'**, pervading the three gunas, tamas (inertia), rajas (movement), and sattva (pure essence) in human body, which kept people free from ailments both mental and physical. (Seed & Rind, 2017). The thought process has its roots in the theory of Ayurveda.

Wilson introduced the term in the European context in 1984 as 'The theory of Biophilia' which pre-existed in ancient India as **'Prakriti'.** In the pursuit of development, Indian architecture and interior design practices lost the roots of prakriti and mindlessly embarked on the journey to build grey infrastructure, leaving behind the green gold gifted to this land.

As interior designers, through the columns of this paper, a few methods and materials are being recommended to bridge the gaps and reconcile with our own identity. By generating effective awareness and government support for this cause at all levels from conception to application, the endeavour shall sow the seed towards 'Prakritik Delhi NCR'. To discuss a few tangible modalities that will control the ever-rising AQI levels and, also regenerate socio-cultural well-being have been discussed below:

To revoke biophilic urbanism in the concrete jungle of Delhi NCR, plantation drives should be implemented in and over built environments like vertical gardening on facades and walls, hanging gardens from balconies, roof gardens, and natural plant curtains. Every year, the Government of National Capital Territory of Delhi (GNCTD) carries out tree plantation drives throughout the States under the annual plantation program, namely, the Delhi Green Action Plan. The plantation programme is being assigned every year by the Ministry of Environment, Forest and Climate Change, Govt. of India under the Twenty Point Programme (TPP).(Forest Department,Govt of NCT of Delhi). Every year, the state is provided with a plantation target by the Central Government with a designated land proportion for the same.

Additionally, free saplings are provided by the government. While the government has formulated and implemented the plantation drive, it is not as widespread as it should be in the city's-built fabric. The reason could be a lack of meticulous distribution of saplings, selection of plants as per weather and soil conditions and maintenance of plants. Deployment of a third-party audit team for fair execution and adoption of the hydroponics system of the plantation (Muhammad Wildan, 2023) shall assure low maintenance, which will help in sustaining plants for a more extended time with less soil and water.

Central Public Works Development (CPWD) norms for green belt in town planning for Delhi NCR should be increased as a mandate. As per Model Plan Bye-laws 2021 for residential areas, it should be approx. 45-55%, and for commercial and industrial areas, it is only 4-5%. As per our observation, the designated green belts in Delhi NCR are exploited with encroachments. Planned and unplanned developments are made in these belts. Strict monitoring from the Govt. administrative bodies is required in case of non-compliance; heavy penalties should be levied.

Other than exterior plantation, biophilic intervention in interior spaces is inevitable. The interior plantation blurs the exterior and interior zones, delving into the green connection of the inmates with the serene nature. Zen corners with water bodies can resolve mental stress and purify internal air. Many indoor species are recommended as they are natural air purifiers; a few examples of indoor plants are snake plants, spider plants, peace lilies, aloe vera, rubber plants and many more. These indoor plants are an energy-efficient recommendation against mechanical measures like air purifiers.

Installing water curtains at the front facades and vestibule entries would work as thermal insulators and create a biophilic layer against air pollution. This biophilic measure boosts health and adds aesthetic value to entrances and facades. Water curtains are a cost-effective solution to fight against airborne diseases by filtering the polluted air's suspended particles compared to expensive processes like artificial rains and mechanical water sprinkling trucks on the road, as recently recommended.

It is recommending dust-absorbing fabrics of biophilic origin, like bamboo cotton fabric (Ajay Rathod, 2014), for public and private buildings be used as window treatments. These fabrics are anti-bacterial, biodegradable and can protect against UV rays. Vegetable dyes and biophilic patterns would also help accentuate the green infrastructure in the dense grey concrete jungle.Placement of big glazed openings, glass facades and corner windows per the solar orientation. Placing openings judiciously as south–south-west direction invites direct sunlight and heat into the buildings as Delhi NCR lies in the globe's northern hemisphere. Large openings with heat absorbing treatments will help harness the disinfecting sunlight that sanitizes interior spaces and restores inmates' mental and physical health into the interior spaces. Other features like skylight openings on roofs and metal and terracotta jalli in balconies and facades can also help concentrate the sun beams into a built environment. The sun beams filtering through jalli panels craft a dramatic light and shadow effect to accentuate the alluring interiors. In high-rise buildings, it is evident that the windows of all the units are not aligned as per solar orientation. At the planning stages, site analysis and placement of towers in alignment with solar orientation should be emphasized.

An energy-efficient and sustainable solution to control the temperature in the built environment is using terracotta tubes to air condition the space. No refrigerant is used; instead, running water flows through the dense assembly of terracotta tubes, evaporates, in this process, cools the air by 6-10 degrees. Mr. Monish Siripurapu, an architect, created this zero-energy, low-tech air-cooling system. (Nitish S, 2019).

Initiatives of street-scaping practices in Delhi NCR are evident. These measures balance grey urbanization with biophilic interventions to a certain extent. To incorporate elements of the biophilic theory, landscaping includes vertical landscaping, animal cut-out forms created by topiary art, intimidating columns and walls of the metro, and flyovers, which have been innovatively painted with colorful artwork. This place-based biophilic intervention reflects the cosmopolitan fabric of the city as the artwork is done from various states. These initiatives act as therapeutic measures which uplift the mood and recreate socio-cultural well-being.

To sustain the momentum of street-scaping, due diligence from the city administrative block is required, and fair incentives to the artist are suggested. To further promote the development of biophilic streets, a five-pointer rating can be introduced in the Twenty Point Programme (TPP) Of the Ministry of Environment, Forest, and Climate Change to boost the Delhi Green Action Plan.

VOC-free paints are the biophilic substitutes for standard pigments or paints available in the market. Khadi and Village Industries developed an innovative new paint made of cow dung; this eco-friendly and non-toxic paint is known as “Khadi Prakritik Paint”. (Agrawal, Shah, & Agrawal, 2023) It is certified by the Bureau of Indian Standards. This anti-fungal, anti-bacterial Khadi Prakritik Paint has two options– distemper and plastic emulsion. Conventional paints release toxic fumes which are harmful.

Bamboo laminates and rattan sheets are a comparatively recent introduction to the market of laminates and finishing materials. These finishing sheets are not only biophilic but eco-friendly and a sustainable substitute. Instead of natural wood and other synthetic materials, these laminates are fabricated from bamboo. A fully grown bamboo takes 4-5 years to grow, whereas a tree takes 20-25 years to be replenished with another such tree. Only a few leading companies like Century Plywood and Merino are offering this segment, with limited choices in patterns and at a comparatively premium range.

Bamboo Concrete Wall –This cost-effective approach uses straight bamboo poles with concrete to create a composite material for building walls. The material combines flexibility and sustainability. Adding bamboo walls to the interior can improve indoor air quality as it releases oxygen and absorbs carbon di oxide while keeping it locked. The natural air purifying quality aligns with biophilic principles that healthier indoor quality. The biomorphic pattern of bamboo has also shown a positive impact on human well-being in the past decade. Cultural significance is deeply rooted in Indian tradition, and integrating bamboo into the construction of walls can evoke a sense of cultural connection.

CONCLUSION

To study and research how the biophilic approach can recreate a sense of social and cultural well-being in Delhi NCR, a deep review of various literatures and case studies on the topic that were propagating and working towards the "Theory of Biophilia" was conducted.

Edward sowed the seeds of biophilic hypothesis; further, Kellert augmented its relation to the built environment. The earlier ponderings of biophilic intervention in the built environment have been delivered in more generalized umbrella terms, which is not specific to any region, culture or climatic conditions.

None of the concepts of earlier theory supports Indian topographical and climatic conditions. To fill the gaps that were identified during the research it can be concluded that the biophilic interventions have to be Indianized to suit the socio-cultural tapestry. Rerooting to our legacy by following satvik life style and utilizing gold of nature in interiors and built environment shall lead to "Prakirtik Delhi NCR". The approach shall decrease the significant consequences of mindless urbanization.

To take conscious steps towards regenerating the wellbeing of humankind in the city the paper recommends few measures that are more adaptable and suited to the ethos of Delhi NCR. For example, biophilic material like bamboo and rattan laminates and terracotta jalli work are good substitute to conventional material as these materials are readily available in India and unconsciously would promote Indian artisans. Paintings and art-work from various states like Madhubani art of Bihar and Warli art of Maharasthra, on the columns and bulkhead of metro grey infrastructure not only brighten the intimidating structure but bring a sense of cultural bonding in the migrants. Both organic and vernacular biophilic elements shall help in not only fighting against the rising pollution levels but migrants would also have a sense of belongingness to the city and develop a feeling of home away from their native place.

Following a strategic research and study pattern, SWOT analysis was performed to devise a concise and crisp conclusion to our endeavour.

SWOT analysis

Analysis objectives

- To study the socio-cultural stratification of Delhi NCR region and the implication of adapting biophilic designs in the city's built environment.
- To re-evaluate and reinforce the efficacy of biophilic design as a defense mechanism against pollution and thus enhance the well-being of communities.
- To understand the barriers in augmenting biophilic measures in the urban fabric of Delhi NCR.
- To propose strategies for integrating biophilic design principles in future urban planning and development projects in Delhi NCR

The paper enforces that the outcome adhering to the biophilic approach can create a conducive living habitat in Delhi NCR by curbing the ever-increasing pollution levels and recreating the cultural identity of the capital of India. The opportunities being offered in the course shall uplift socio, economic and cultural strata of the community. Following the words of the honourable Prime Minister Shri Narendra Modi, One may get a positive outcome in the pursuit to build 'Humari Dilli, Prakirtik Dilli.'

''We, the present generation, have the responsibility to act as a trustee to rich natural wealth for the future generations. The issue is not merely about climate change;it is about climate justice''(Prime Minister Shri Narendra Modi) (narendramodi.in)

Internal Factors

Strengths +	**Weaknesses –**
• Pre-existing roots of biophilic consciousness in India- Prakirtik • Delhi NCR has rich natural resources that support green drive • The cosmopolitan fabric allows various options to amalgamate vernacular biophilic approach that delves into the social well-being of the city's inmates. • People have welcomed and appreciated interventions like vertical gardening and street landscaping, as well as the organic and vernacular dimensions of biophilia. • In the market, few options of biophilic material have been introduced as substitutes for conventional products.	• Forgetting Indian roots of construction which was in sync with natural habitat. • Lack of general awareness towards the prudence of biophilic approach in the built environment • The cosmopolitan doctrine of Delhi NCR makes it challenging to propagate awareness among the heterogeneous community in terms of linguistic and education levels. • The population of Delhi and the NCR region has multiplied the complications of adapting regenerative measures of biophilic designs. • No government intervention in controlling rates of biophillic material. • The concept of Biophilia is not emphasized as a part of the Government curriculum for Interior design students.

External Factors

Opportunities +	**Threats –**
• Biophilia is a way to construct energy-efficient transformative habitats and unconsciously help India in adapting sustainability practices. • Acceptance of biophilic materials would offer new avenues for Indian industries to establish a new tangent in the building material market. More competition would give way to refinement and generate the 'Need' for these products, which shall improve the socio-economic conditions within the country. • Promotion of Indian manufacturers of biophilic materials and solution providers on a large scale would reinforce campaigns like 'Vocal for Local' and 'Made in India'. As a result, it would provide a wider working platform to Indian suburbs. • Reinforcement of the biophilic approach can lay the foundation for widespread usage of vernacular design and materials.	• Mindless urbanization and adaptation of conventional material in interior design practices would keep on generating toxic compounds that contaminate the internal air of the built environment. • Knowing and getting aware is not enough, adaptations of these materials are imperative by Indian interior designers. If these brand ambassadors fail to accept Indian biophilic design elements it shall give way to foreign designers to take credits of our resources. • Many foreign companies have already researched and indentified India as a huge market to trade these materials; it could be a threat to 'Vocal for Local' campaign. • Not so cost-effective biophilic material, which is getting exported, shall loose the battle to cheap conventional options available in market readily if not addressed or spoken about now. • No wide spread market and competitors for 'Made in India' biophilic product would hamper India's progress.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors

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Evaluation of Perception of Public Spaces in an Indian city

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Abstract— Public spaces are an intrinsic part of our urban life. How these spaces are perceived and how this perception is linked to the physical and perceptual characteristics of the spaces is an important step towards understanding our urban spaces. Such studies can aid towards the design of better urban public spaces. The paper reviews the research work which have sought to work with the characteristics features of urban spaces and people's perceptions, including the Public Space Index (Mehta, 2014) which uses the five dimensions of meaningful activities, inclusiveness, pleasurability, comfort and safety. It further outlines the study of public spaces in an Indian city, broadly based on the Public Space Index and attempts to analyse the outcomes with reference to the characteristics, history and functions of these spaces. The study has been carried out through perception surveys conducted among users of two public spaces in the historical town of Gwalior.

Keywords: public space; meaningful activities; inclusiveness; pleasurability; comfort and safety

INTRODUCTION

Place is the backdrop of each event of the lives of each of us and is directly and indirectly a component of our thoughts, emotions and experiences. "People and the places where they reside are engaged in a continuing set of exchanges; they have determinate, mutual effects upon each other because they are part of a single, interactive system." (Sax,1991). Architecture can be said to be the making of places (Schulz,1976) and public spaces are the most telling places experienced by urban dwellers.

Public spaces have been the centre of urban settlements since the earliest times. Be it the Greek agora, the Roman forums, the medieval squares or the Indian market streets, the pulse of the city was in the life around the public places.

In contemporary times, public spaces have multiple typologies from squares, recreational parks, sport arenas to even commercial streets and shopping malls. While public spaces have been analysed from Vitruvian times with reference to its visual perceptions, psychological perceptions have been the focus of studies since the 1960s. Picking up from Lynchian theories and the field of environmental psychology, study of people's perceptions have gained momentum in built space studies.

LITERATURE REVIEW

The formative work on imageability in cities by Lynch (1960) led to consolidative work on people's perceptions of urban spaces. Herzog (1992) studied preferences in urban spaces with reference to spatial constructs. The spatial dimensions of openness and definition in urban setting figured prominently, as in the perception of natural spaces (Kaplan 1979). Preferences and characteristics of urban spaces such as complexity, coherence, identifiability and mystery were studied (Herzog et al,1984; Kaplan et al 1989).

Nasar investigated legibility and likability through evaluative assessment of built environments. His study works on the premise that perception and cognition can have probabilistic relationships to each other and the physical characteristics of the environment. The liked features can be classified into five kinds of attributes – naturalness, upkeep or maintenance, openness or vista, historical significance or elements of historicity, and order. Thus, it shows a linkage with physical characteristics as well as meanings associated with them. (Nasar, 1997)

Carmona (2015) has explored contemporary public spaces in London through a mixed methods approach to put forth a new narrative of re-defining the characteristics of public space. Aguila et al (2019) hypothesize affect, cognition, physical setting, and behaviour as four facets in the theory of place in public space and test it using facet theory with recommendations for place-making. Place theory in urban design emphasizes the understanding of the cultural and human-related characteristics of the physical space. It looks at place through sociological and psychological perspectives to link the spatial with its meanings through context, experience and memory. (Trancik,1986)

Perceived Environmental Quality Indices (PEQIs) have been developed to gauge perception of environmental quality with the overall goals of guiding environmental policy through gauging the environmental impacts of proposed projects, judging effectiveness of environment protection programs and communicating the trends in environmental quality to citizens, officials and decision-makers. In the US, PEQ indices were developed for scenic assessment, environmental quality of sensitive natural landscapes and developmental projects. PEQI differs from Environmental Quality Index (EQI) which are quantitative measures of environmental performance. PEQI measures the perception of environmental performance, thus incorporating the cognitive and psychological perception by people. Typical issues and examples of perceiving environmental quality have been discussed with reference to research design. (Craik & Zube, 1976).

PEQIs with reference to urban residential environments have been tested by researchers in different settings. These works have developed indicators of perceived environmental quality. (Bonaiuto et al, 2003; Fornara et al, 2010).

Public space evaluation is a primary step towards designing better urban environments. Mehta (2007, 2014) has sought to work with the characteristics features of urban public spaces and people's perceptions. The Public Space Index, used to assess quality of public spaces, measures the five dimensions of meaningful activities, inclusiveness, pleasurability, comfort and safety. (Mehta, 2014). Evans et al (2019) have carried forward Mehta's Public Space Index with reference to public parks, testing its versatility. Gokce & Chen (2021) have used an empirical assessment of sense of place over three spatial scales – building, street and neighbourhood.

METHODOLOGY

This study strives to investigate place dimensions on the scale of urban public spaces. The methodology used by Vikas Mehta (2007, 2014) had developed the Public Space Index (PSI) to measure quality of public spaces such as streets, plazas, squares and small urban parks in the American context. The 2014 study applies the PSI measuring upto 45 variables to assess four public spaces in Tampa, Florida with a total of 77 respondents. (Mehta 2014)

Herein, the public space survey used is broadly based on the dimensions developed by Vikas Mehta (2014). The questions have been framed with reference to multiple studies (Mehta,2014; Evans et al 2019; Fornara et al 2010), dovetailed to suit the context of the public spaces being studied herein. While Mehta (2014)'s Public Space Index is based on observed data and user rating, herein the study is based on users' responses. Thus, it is an evaluative perception of users. The purpose is to evaluate the public spaces in people's perception; at the same time, the study checks out the validity of the methodology in context to Indian urban spaces.

The five dimensions of public spaces being studied herein are meaningful activities, inclusiveness, pleasurability, comfort and security. The questionnaire addresses these five dimensions through 36 items on a Likert's scale of 1 to 7 (Table 2). The sample consists of users of the public spaces studied. The respondents are users on site who voluntarily agreed for the survey. Thus, the sampling process is haphazard convenience sampling. The surveys are conducted by a team of architectural student volunteers, trained for the purpose.

The study is carried out in two public spaces in the city of Gwalior in central India. Total sample size is approximately 40 for each place. This study has also attempted to compare the resultants for average public group and an expert group. The expert group consisted of 20 professional architects & urban planners familiar with the area.

The public place study has been limited to 2 places in the case study city of Gwalior and a limited sample size, primarily due to time and resource constraints of an academic study. The study can be replicated on multiple external public spaces with larger samples for more robust conclusions.

The two public spaces studied are in Gwalior, a million plus city in central India which has a prominent historical past as a historical capital city of the region.

Public space A: Maharaj Bada square

Maharaj Bada square is the historical square from the time of the origins of the Lashkar settlement of Gwalior (1811). Its current built form is quite similar to its development in early 20th century. The square was designed broadly on Baroque style western examples. Its major buildings include the General Post office, central library, Town hall and a major bank's local headquarters, the styles varying from neo-classical, Victorian, Art-Deco, to Maratha and Indo-Saracenic. The overall built character of the space is seen in Figure 1. The space has a distinct sense of enclosure and a predominant heritage character.

It is at the heart of the city's commercial district with a range of small-scale shopping establishments. The area is popular for regular shopping in dresswear, footwear, home-decor and accessories. There is a high level of commercial activity in this precinct.

Fig 1 Public space A -Maharaj Bada square (figure source: Ar. Siddharth Jadon)

Public space B: Baija Taal Precinct

Baija Taal was built near the erstwhile royal headquarters of Moti Mahal palace, a few hundred metres from the river front as a famine relief operation in the middle of 19th century. It is an oval tank with steps all around leading to the water. The precinct is located quite centrally with reference to the city. Since amalgamation with the Indian Union in 1956, the Motil Mahal palace has held major administrative offices of the state and the water body has been a scenic spot with its stone pavilions in the backdrop of the palace. In the last decade, the precinct has seen some serious heritage conservation efforts and the area abutting the water body has been developed with food joints, stone park and amenities. Currently it is a fairly popular recreational hang-out space with multi-color lighting, boat-ride facility and formal and informal eating joints nearby. It is also the occasional venue of cultural events such as dance or music shows.

Fig 2: Public space B -Baija Taal precinct

Data Compilation and Analysis

5.1 Respondent profile:

Table 1 respondent profile

	Public Space A	Public Space B
Total	42	40
Male	33	21
Female	9	19
Age 18-44	22	25
Age 45-64	19	14
Age 75 plus	1	1

Data compilation and analysis:

Descriptive statistical analysis has been used to understand the perception of public spaces. Standard deviation has been used to explain the variance in the data set as a measure of dispersion. Below are given the items of each of the sub-dimensions as tested through the questionnaire and their descriptive statistics.

Table 2: Data compilation of item responses of the dimensions:

		Public space A		Public space B		Public space A	Public space B
Item	Dimensions and its Items	mean	std dev	mean	std dev	Mean *	Mean *
	Meaningful activity (MA)	**5.38**	1.6	**5.3**	1.26	**4.30**	**4.82**
MA1	There are many things to do here	5.31	1.67	4.80	2.04	5.0	4.56
MA2	I like the activities I can do here	5.4	1.5	5.03	0.92	4.82	5.06
MA3	The place has suitable activities for all	5.19	1.44	3.98	1.25	4.36	4.56
MA4	People interact with each other here	5.98	1.55	6.1	1.22	4.73	4.58
MA5	I can meet up with friends here	5.38	1.89	6.03	1.14	3.0	5.25
MA6	There are community activities here	5.05	1.55	5.88	0.97	3.91	4.88
	Comfort (CO)	**4.37**	1.43	**4.8**	1.17	**3.74**	**4.67**
CO1	The place is easy to access and use	6.21	1.02	6.5	0.72	4.82	5.85
CO2	The space is comfortable to spend time	4.76	1.72	5.63	0.84	3.73	5.08
CO3	There are places to sit comfortably	4.02	1.88	6.2	0.97	3.18	5.29
CO4	The place is well shaded	3.83	2.02	4.2	1.4	3.91	4.81
CO5	The place can be used at any time of day	6.14	1.32	3.63	1.72	5.36	3.49
CO6	The place is too noisy (R)	1.26	0.63	2.68	1.38	1.45	3.49
	Perception of Safety (SP)	**5.93**	1.35	**5.45**	1.18	**4.92**	**4.69**
SP1	the place is easily connected to other streets	6.55	0.86	6.43	0.55	4.98	5.89
~~SP2~~	~~there are no dead ends here~~	~~5.29~~	~~2~~	~~3.98~~	~~2.03~~	~~5.82~~	~~4.09~~
~~SP3~~	~~there are dark corners I don't like (R)~~	~~4.26~~	~~2.07~~	~~4.68~~	~~1.38~~	~~5.22~~	~~3.33~~
SP4	The traffic makes this place unsafe to use (R)	3.43	1.93	4.73	1.09	2.64	4.11
SP5	I feel safe because it has surveillance	6.29	1.35	4.6	1.84	4.27	4.0
SP6	I feel safe because there are enough people around	6.33	1.34	6.23	0.92	5.64	5.0
SP7	this place is safe during day time	6.48	1.04	3.85	1.7	5.27	6.11
SP8	this place is safe during late evening hours	6.36	1.41	6.1	1.06	5.73	3.33
SP9	This place has sufficient lighting after sunset	6.24	1.34	6.15	1.14	5.91	3.67
SP10	I feel safe coming here alone	6.4	1.38	5.88	1.2	6.0	3.78
SP11	Women find this place safe	6.57	1.11	6.25	1.06	5.0	4.33
SP12	The crowd here is well behaved	4.67	1.71	4.28	1.3	3.73	5.44
	Inclusivity (IN)	**4.88**	1.79	**5.35**	1.44	**5.21**	**5.19**
IN1	People of all ages use the space	5.86	1.69	4.5	1.68	5.27	5.67
IN2	Many women use the space	6.33	1.32	6.15	1.44	6.27	5.44
IN3	Children use this space	3.64	1.9	5.93	1.4	3.73	5.11
IN4	The use of space is controlled by gates (R)	4.98	1.54	5.23	1.53	6.09	5.11
IN5	Security guards stop some people from using the space (R)	4.76	2.15	5.31	1.36	5.36	5.78
IN6	All people are not encouraged to come here (R)	3.74	2.12	4.98	1.25	4.55	4.0
	Pleasurability (PL)	**4.86**	1.41	**5.07**	1.14	**4.91**	**5.59**
PL1	I find the space very attractive	6.19	1.45	6.08	0.72	6.27	5.89
PL2	This space is quite interesting	6.19	0.94	5.95	0.84	5.91	6.22
PL3	The space has distinctive architectural features	5.71	1.35	6	0.97	6.82	6.33
PL4	It has nice landscape features	3.62	2.25	4.58	1.4	4.55	5.78
PL5	It is easy to spend time here	6.17	1.46	6.1	1.72	4.73	6.0
PL6	This space is too crowded (R)	1.26	0.99	1.73	1.38	1.18	3.33

Note: Likert scale 1 to 7 from strongly disagree(1) to strongly agree (7). 4 indicates neither agree nor disagree

Note: (R) Likert scale responses reversed for items . * values of expert's responses

Note: high std dev>1.5 shows non-collinearity in perception

All the items showed p value <0.01, hence construct validity is acceptable. Of the 12 items for the dimension of sense of security, 2 were deleted from the final analysis, since the high standard deviation indicated lack of measurement reliability, attributable to improper understanding of question by respondents.

Public Space A - Maharaj Bada:

It is observed that for 32% of the items the standard deviation is more than 1.55, indicating a high variance in non-collinearity in perception among the respondents. The most convergent and negative viewpoint was on perception of crowd and noise. Among all the dimensions, perception of safety is the highest (5.93). The overall mean of all the subdimensions for perceptive evaluation is 5.08.

Looking at the gender variation, female perception is lower in the average with a marginal comparative higher value for inclusivity. But considering the small sample size and low percentage of female respondents, this cannot be considered a universal conclusion.

The most acute low ratings are on perception of overcrowding (1.26) and noise pollution (1.26) i.e. indicative of an overcrowded and noisy environment. The high standard deviation on inclusivity items reflects the relative difference in male and female perceptions with a lopsided male sample. [values of mean (& standard deviation) for male & female : 4.81(1.9), 5.17(1.24) respectively]

Public Space B - Baija Taal:

It is observed that for about 18% of the items the standard deviation is more than 1.5, indicating a high non-collinearity in perception among the respondents for those items. But the mean of standard deviation of items for each dimension is less than 1.5, indicating validity of acceptance of the mean. Analysis of the mean of items for the comfort sub-dimensions show that while the place is perceived as easy to access, use and spend time in, shaded spaces are neutrally perceived, and space is perceived as noisy and unsuitable for use at all times i.e. lack of shaded spaces makes it unsuitable for hot afternoons. On a rating scale of 1 to 7, the overall mean is 5.19 with the mean value of comfort, pleasurability, inclusivity, meaningful activity and perception of safety at 4.8, 5.07, 5.35, 5.3 and 5.26 respectively.

Overall observations:

The responses to the comfort items reflect need for proper environmental design in the public spaces with reference to the climatic factors and noise reduction. Pleasurability items have shown a positive trend except for the sense of overcrowding. Thus, it reflects a need for higher number of functional public spaces in the city. Perception of security is fairly good.

Looking at the gender variation, female perception is marginally higher in the average, but marginally lower for the dimension of meaningful activity and safety.

Age group wise variation is not statistically relevant.

RESULTS

The overall perception above 5 rating indicates a moderately positive perception of the public places. The radar graphs reflect the perception of the users to the two spaces under the five dimensions. Meaningful activities and pleasurability is almost same for the two places, measures for inclusivity and comfort have much scope for improving the place perception. (fig 3). It is notable that both these spaces have heritage linked to the city's historical past. The heritage buildings are active functional spaces and the familiar backdrop of the public spaces

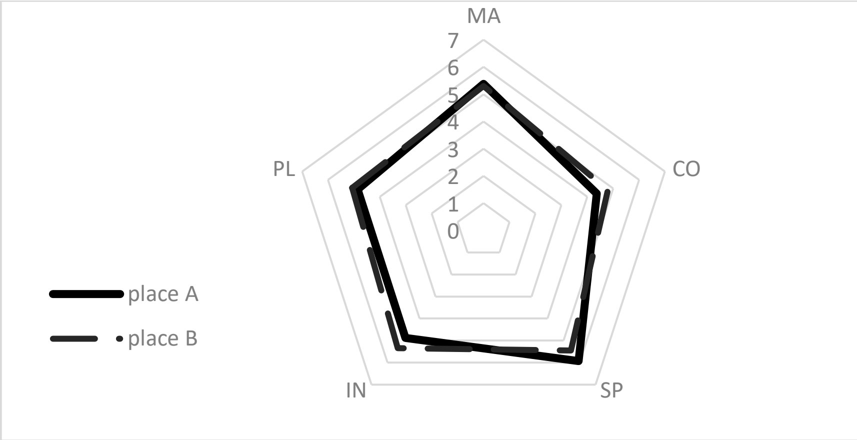

Fig 3: Comparative radar diagram of the 2 public spaces

Fig 4: Comparative radar diagram of the public and expert evaluation

The comparison with professional expert responses (fig 4) has shown marked differences, which differ for the two places. In terms of security and pleasurability, public give a higher rating in both places. The results reflect a higher expectancy of performance of spaces by professionals.

CONCLUSIONS:

This paper has explored the potential of public perception surveys towards evaluation and design of public spaces in our cities. Overall, the study has shown the scope for improvement in the public spaces studied for higher evaluative assessment, especially for the comfort, pleasurability and inclusivity items. The limited size and haphazard type of the sampling has restricted the study from drawing definitive conclusions, but the study has shown the potential of the methodology for assessing the public spaces for practical interventions.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Planning for Sustainable Carrying Capacity using SAFE Approach: Trimbak Town, Nashik

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Abstract – The world population is getting concentrated in urban areas across the globe. In the year 2015, 54% of the population lived in urban areas, which contributed to 80% of the world's Gross Domestic Product (GDP). It is a challenging task for planners to manage the urban system with the available resource constraints. The urban system has a certain carrying capacity to accommodate the population. This paper aims to contribute to understanding the role of carrying capacity of built environment in subjective well-being of residents. The urban system has a certain carrying capacity to accommodate the population. Quality of life decreases due to an increase in population in the urban system when it reaches beyond the carrying capacity. This paper calculates carrying capacity of a tourist city through critical infrastructure of water supply and solid waste with and without considering tourist population and understanding its role in well-being of residents of the city. Carrying capacity assessment plays an important role in developing the built environment in a planned manner by restricting the growth in areas where the carrying capacity has already been reached. It is important to look forward to the carrying capacity assessment from a land use planning perspective to ensure integration of land use, infrastructure, and the carrying capacity. Sustainable Accommodation through Feedback Evaluation - SAFE Approach Model has been used here to assess the infrastructure carrying capacity of Trimbak, Nashik, Maharashtra. Tourist population of Trimbak majorly includes regular devotees coming to Trimbakeshwar temple which is one of the 12 Jyotirlingas in India. Trimbakeshwar is also known for Kumbhmela which comes after 12 years. The method considers the land needed for infrastructural uses within the urban system and the land required determines the carrying capacity. New infrastructure assets should be prioritized, planned, designed, built, and operated to account for the climate changes that may occur over their lifetimes. The carrying capacity is assessed based on the land requirement. GIS technique is used to make the necessary assessment of the carrying capacity of the system. The paper concludes at how carrying capacity changes when tourist/ pilgrims' population is taken into consideration.

Keywords: Well-being; Built Environment; Carrying Capacity; Infrastructure; SAFE Approach; Quality of Life

INTRODUCTION

Improving quality of life in cities is becoming an increasingly critical issue for urban planning. The rise of urban populations worldwide, caused by rapid population growth and urbanization processes, makes urban quality of life relevant to more and more people. The physical characteristics of cities change to accommodate new residents. A deeper knowledge on the relationship between the built environment and quality of life in cities can play a catalytic role in shaping present and future urban development. (Mouratidis, 2021) Enhancing urban quality of life is turning into one of urban planning's most important concerns. Urban quality of life is becoming increasingly important to a growing number of people due to global urban population growth and urbanisation processes. It is also important to understand city limits and carrying capacity as the carrying capacity plays an important role in developing the urban system in a planned manner by restricting the growth in areas, where the carrying capacity had already reached to their maximum limit. It is also important to understand the carrying capacity assessment from a land use planning perspective to ensure integration of land use, infrastructure, etc. It is well documented that continuous and rapid urbanization will increase the exposure of urban populations to health and wellbeing risks. The built environment sits at the heart of public health and wellbeing. Planning the infrastructure by using a sustainable approach can enhance the quality of life.

Infrastructure is an important determinant for maintaining a quality of life in an urban system. Carrying capacity helps in the assessment of the population that a particular urban system could sustain for a particular set of resources. In this study, the land is used to evaluate the carrying capacity considering infrastructure as an important parameter. The work concentrates on the valuation of the existing carrying capacity based on the land-use in the city of Trimbak for the year 2019. The areas used for infrastructure in the city are accounted for the valuation. If this limit is crossed, then the nature will react by imposing pressure to resist the abrupt growth and development of the people resulting into equilibrium.

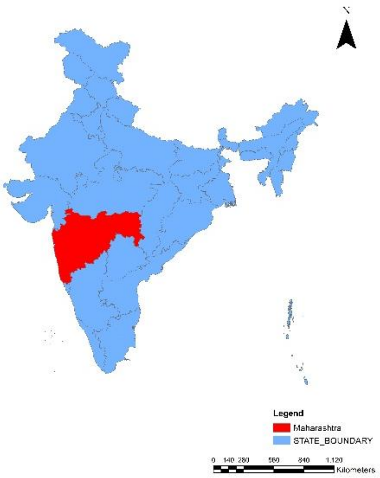

Figure 1: Maharashtra showing Nashik

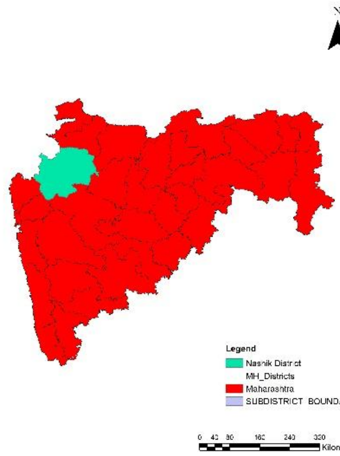

Figure 2: Maharashtra showing Nashik

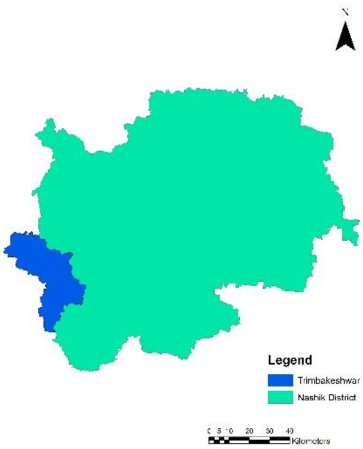

Figure 3: Nashik showing Trimbakeshwar

Figure 4: Trimbakeshwar Tehsil showing Trimbak town

Trimbak is a ‘C’ class Municipal Council in Trimbakeshwar Tehsil in Nashik district. Area under Trimbak Municipal Council lies between 19.56^0 North Latitude and 73.32^0 East Longitude. Nashik-Jawhar Road State Highway 30 is passing through Trimbak Municipal Council. The origin of the sacred Godavari River is near Trimbak. The river Godavari and Ahilya flows through municipal limit. The land within the municipal limit is having irregular contours, having gentle slope and fairly plane towards east of Trimbak-Jawhar road. Trimbak has a height of about 712 m above mean sea level. At present, the town is being supplied with water from Amboli dam. Water from Amboli dam is lifted up at

Water treatment plant situated on Nil Parvat. Also, water from Ahilya dam is lifted up at Gadhai Water Treatment Plant. Water treatment plant is then distributed to the whole town through the network of distribution mains. In Sinhastha Kumbhmela period, Gautami-Godavari water supply scheme is also completed.

LITERATURE REVIEW

The carrying capacity is the maximum number of people that can be supported by the environment of that area through optimum utilisation of available resources (Malthus, 1798). Carrying capacity has a different perspective: social, cultural, political, ecological, etc. Quality of life decreases due to an increase in population in the urban system when it reaches beyond the carrying capacity. The pattern and extent of resource usage serves to be the primary factor that affects the carrying capacity. It is highly dependent on the socio-economic status of people. Sustainability can be measured by the carrying capacity. The carrying capacity concept can be applied to urban planning and development to maintain the delicate balance that currently exists between the built and natural environments. High levels of consumption are accompanied by significant 22 waste production and sewage buildup that cannot be effectively assimilated within the local carrying capacity. (IIT, Department of Civil Engineering, IIT Guwahati | Centre of Excellence, 2011-12)

Infrastructural capacity level: At this capacity level, the major factor of evaluation is the infrastructure development. Here the intensity and pattern of resource usage is estimated for the development of infrastructure like water supply system, sewage system, transportation system, waste disposal system, etc. (IIT, Department of Civil Engineering, IIT Guwahati | Centre of Excellence, 2011-12)

Environmental capacity level: This level basically reflects the present state of the environment with respect to productivity. One can easily understand the state of productivity of the environment, e.g. agricultural productivity, by evaluating the past data. Another way of assessment is the availability of clean air and water, low pollution, etc. (IIT, Department of Civil Engineering, IIT Guwahati | Centre of Excellence, 2011-12)

It is very challenging to estimate or compute carrying capacity. According to Arrow et al. (1995), carrying capacity is not constant but rather is influenced by a variety of factors, including patterns of production and consumption, innovation utilization, and complex relationships between preferences. There are various methods to calculate carrying capacity like Graphical model, Uni constraint model, IPAT equation, Ecological footprint model, Energy analysis model, Pressure-State-Response model

This research will be using method of "Sustainable Accommodation through Feedback Evaluation (SAFE)" proposed by the Indian Institute of Technology, Guwahati. Carrying capacity based operational framework would help in reaching the goal of sustainable development. The equitable quality of life of the people will be enhanced by upholding the ecological balance, minimize environmental degradation by maintaining socio-economic development. There is a limit of available resources for which the growth of the city and carrying capacity should be taken into consideration. We spend some two thirds of our lives in urban environments, and approximately 90% of our lives indoors (United Nations, 2018; World Health Organization, 2013). Continuous and rapid urbanization will increase the exposure of urban populations to health and wellbeing risks.

METHODS

The study covers only the inner core of the Trimbak which is of 1.84 sq.km. As per the 2011 census, the total population of Trimbak Municipal Council was 12,056 whereas 1327 population was added in 2019 i.e. total 13,383, indicating the growth rate of 25.04% during 2001-2011. The population density of Trimbak Municipal Council is 63 persons per hectare. The original municipal council is divided into 17 wards. It is situated at a distance of 28 kms towards west of Nashik city. Trimbak is located 123 kms from Shirdi. Total tourist population is 1,30,72,625 per year in the Trimbak.

Sustainable Accommodation through Feedback Evaluation 'SAFE' carrying capacity approach is applicable for eco sensitive areas, hilly areas, watershed, urban areas that will ensure hazard free sustainable urban advancement which are suitable for Trimbak, Nashik. In this approach, the ecological footprint is used to determine the sustainable carrying capacity of watershed covering urban area under consideration. The SAFE Approach model was developed by Indian Institute of Technology, Guwahati. This method has been used in various studies previously for Guwahati (IIT, Department of Civil Engineering, IIT Guwahati | Centre of Excellence, 2011-12), Patna (Kumar, 2017), Gwalior (Jayeshkumar Bhagwat, 2021).

Most of the data is collected through secondary survey and some data like tourist data was collected by primary survey as secondary data was not available. So, secondary and primary data is used for the study. Trimbak is selected for the study because of its topography, and other features like hilly urban area, watershed area, eco sensitive area, etc. The study of carrying capacity for Trimbak is important because the current tourist and pilgrims' population is very high and as it is located in hills/mountains like Brahmagiri, there are chances of deterioration of natural resources. The population of Trimbak is also growing and with the help of various schemes and policies, the development of the town is also expected in coming years. This study not includes the Kumbhmela population as it comes after every 12 years and for which various provisions has been done for that population.

RESULTS

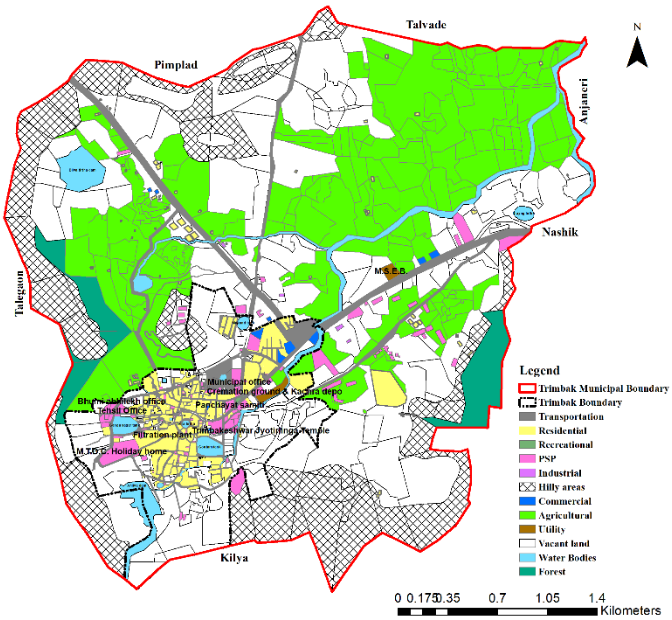

Figure 5: Existing Land Use Map, 2019

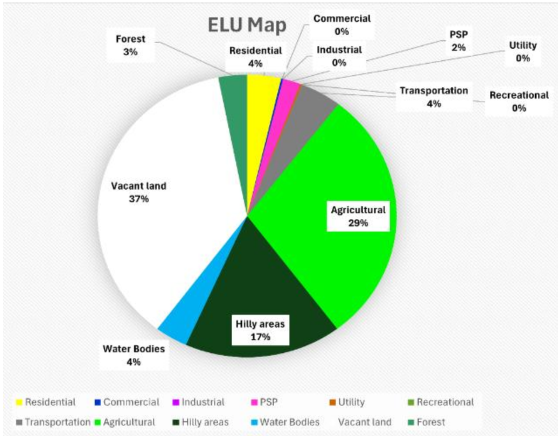

Figure 6: ELU Percentage

Valuation of carrying capacity on SAFE approach area as follows:

Step 1: Watersheds are delineated by using GIS tool.

Step 2: Cities consist of Developable and Non-developable areas and areas which are unsuitable for development i.e. non-developable areas. Non-developable areas of the delineated region are demarcated by using geospatial tools. Non-developable areas includes high slopes, forest areas, hilly areas, water bodies, streams, drainage, etc. Therefore, developable area is marked with respect to different developmental activities. The non-developable areas mainly consist of land which was identified by the weighted overlay method. Equal weight was given to 4 parameters such as proximity to an urban area, distance from road, distance from river/ streams, slope of the demarcated region.

According to this, AU = AD + AND

Therefore, AND = AU – AD

= 11.793 – 8.46 = 3.34 sq.km.

Step 3: Calculation of area requirement for different infrastructure (ADIF)

ADIF = AIF + AR

= 8.028 + 0.43

= 8.46 sq.km.

Step 4: Net residential area for settlement development can be calculated by:

AU = AND + AIF + AR

Therefore, AR = AU – (AND +AIF)

= 11.793 – (3.34 + 8.028)

= 0.43 sq.km

Step 5: For floor area ratio, base FAR is used according to UDCPR which is national level floor area standard value. Analyzing present population and considering future prospects of average floor area requirement (S) is being considered as 0.0005 sq.km. per head. (Sarma, 2012). In absence of any FAR guidelines, a value of 1.5 can be used for initial value. This value is based on the general trend observed so far in Indian condition Step 6: Floor Area Ratio is defined as FAR = AF / AP

Proposed SAFE Approach method will consider an acceptable FAR for which initial value of FAR is needed. This value can be taken from guidelines like UDCPR or from documents of Urban Local Bodies. In Trimbak's case, we consider FAR as 110 or FSI as 1.1 which is a basic FSI according to UDCPR, the permissible value for the city.

Step 7: Based on the overall study, the carrying capacity of the area can be calculated as:

CC = AU – (AND + AIF) * FAR / S

CC = 11.793 – (8.028 + 3.34) * 110 / 0.0005

= 94,600

The carrying capacity for the suitable development area in the Trimbak city by SAFE approach is 94,600.

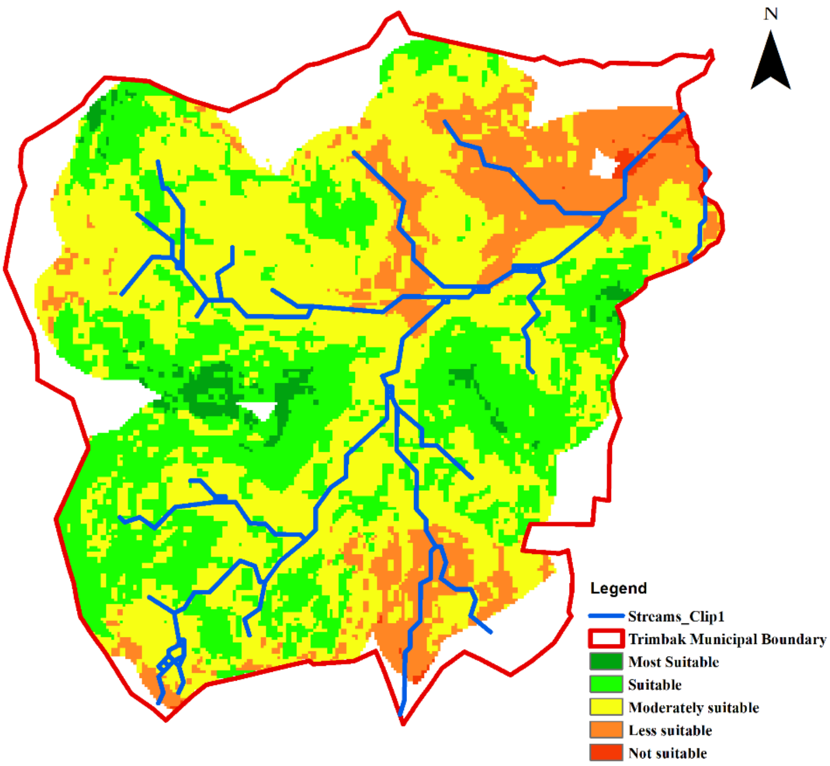

Figure 7: Land Suitability Analysis

Table 1: Area required for the SAFE Approach method

Sr.No.	**Description**	**Notation**	**Area (Sq.km.)**
1	Developable Area	AD	8.46
2	Non-Developable Area	AND	3.34
3	Total Urban Area	AU	11.793
4	Floor Area Ratio	FAR	110
5	Floor Area Requirement per head	S	0.0005
6	Total infrastructure area	AIF	8.028
7	Total residential area	AR	0.43

Table2: Land Suitability Analysis Criteria

Sr.No.	Criteria	Buffer zone	Suitability class	Rank
1	**Distance from River**	0-200 m	Not suitable	5
		200-400 m	Less suitable	4
		400-600 m	Moderately suitable	3
		600-800 m	Suitable	2
		800-1000 m	Most suitable	1
2	**Distance from Road**	0-200 m	Most suitable	1
		200-400 m	Suitable	2
		400-600 m	Moderately suitable	3
		600-800 m	Less suitable	4
		800-1000 m	Not suitable	5
3	**Distance from Urban area**	0-100 m	Most suitable	1
		100-200 m	Suitable	2
		200-300 m	Moderately suitable	3
		300-400 m	Less suitable	4
		400-500 m	Not suitable	5
4	**Slope**	1-11 m	Less suitable	4
		11-21 m	Suitable	2
		21-31 m	Most suitable	1
		31-41 m	Moderately suitable	3
		41-51 m	Not suitable	5

Discussions

The assumptions considered for the study are not only the census population but also to find out developable area by considering the pilgrims' population. Projected population for 2024 is assumed as 16,400. Therefore, total population calculated as 1,30,89,025 including pilgrims' population and projected census population. From the calculations, Trimbak town's carrying capacity is calculated as 94,600 which is much lesser than the future projections of population. Therefore, to improve standard of living and accommodate the excess population, Trimak will need more developable areas. this approach was applied to to the pilgrimage town of Trimbak, and the results show that the town is experiencing more demand for pilgrims than it can accommodate. It is necessary to make sufficient provisions for the infrastructures to accommodate an increase in the population.

There are various schemes, policies by Government which are implemented to make infrastructural provisions in Indian urban system and also some schemes are implemented for Heritage or Pilgrimage cities or towns like Pilgrimage Rejuvenation and Spiritual, Heritage Augmentation Drive (PRASHAD), Heritage City Development Augmentation Yojana (HRIDAY), Smart City Mission, Atal Mission for Rejuvenation & Urban Transformation (AMRUT), Housing for all by 2022 mission, Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Swaccha Bharat Mission (SBM), etc. Under PRASHAD scheme, Trimbak is the only city in Maharashtra which is selected for the overall development of the city. This paper includes total population as projected population for 2024 is 16,400. From the calculations, Trimbak town's carrying capacity is calculated as 94,600 which is much lesser than the future projections of population. So, Trimbak will need more developable areas to accommodate the surplus population to improve quality of life.

CONCLUSION

The quality of life is directly related to the number of persons an urban system can carry. If there are fewer resources, quality of life reduces. Urban carrying capacity can be easily calculated using 'Sustainable Accommodation through Feedback Evaluation' (SAFE) method. This method has been used for Trimbak pilgrimage town and it indicates that, Trimbak is having much more pilgrimage pressure than its capacity. So, it is better to use SAFE method to plan Trimbak in a better way. For this, it is necessary to make sufficient provisions for the infrastructures to accommodate increase in the population. This will help to improve quality of life and to plan sustainable infrastructure in the city.

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Assessing Healthcare Accessibility of Tribal Settlements: Core Tiger Reserve area, Melghat Region

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Abstract— Disparities in healthcare accessibility need to be re-evaluated in the context of developing countries, particularly in tribal regions. The criteria for allocating healthcare facilities are typically based on demand and supply. however, this varies for remote and hilly areas which are mostly inhabited by tribal populations. This paper aims to assess healthcare accessibility in tribal regions using spatial accessibility methods. An assessment has been conducted to determine the accessibility of villages in the tribal region of Melghat in the Amravati District. This was done using methods of travel scenarios, the 2 Step Floating Catchment Area Model (2SFCA), and healthcare preferences. Certain parameters have been identified to assess the accessibility of healthcare in villages. These parameters include healthcare spatial coverage, capacity, and preference. In the initial phase, the catchment area has been determined based on the speed and time taken in various travel scenarios. In the next step, the accessibility of healthcare centres is measured by considering the population ratio and then by summing up all values of the service areas within the catchment area. It has been observed that disparities in healthcare accessibility exist due to road conditions, mode of transport, transport availability, travel time, affordability and personal preferences. The study aims to Assess the Healthcare Accessibility of Tribal region using the methods of Spatial Accessibility and social aspects of accessibility. This study will help researchers and policymakers identify underdeveloped areas in tribal regions, leading to improvements in infrastructure such as road networks and better allocation of PHCs.

Keywords: Healthcare accessibility; Tribal Population; Catchment area; 2SFCA Model; Social aspects.

INTRODUCTION

Healthcare accessibility is the ability to obtain necessary healthcare services when needed, including physical, financial, and cultural barriers. Healthcare accessibility refers to an individual's ability to access necessary healthcare services when they require them. It takes into account the availability of services, affordability, proximity to healthcare facilities, cultural and linguistic compatibility, and other factors that may affect one's decision to seek or receive care.

When it comes to healthcare in tribal regions, accessibility is critical. These areas often face unique and complex challenges, so addressing them requires a deep understanding of the contributing factors and implementing targeted solutions. Many tribal regions are located in geographically isolated areas with poor infrastructure, making it difficult and time-consuming to reach healthcare facilities. Tribal communities often experience high poverty rates, making it difficult to afford healthcare costs, transportation, or medication.

Melghat Core Tiger Reserve is the hilly forest region of 55 small villages, known as one of the most underdeveloped regions in Maharashtra. The core area is a part of two talukas in Amravati District partially. In both the Talukas of tribal population, For the population of over 3 lakhs in Melghat, there is only one Sub-District hospital, two rural hospitals and 11 Primary Health Centres (PHC) (Ashish Satav, 2015). It is a Region with highest numbers of malnutrition and infant mortality cases (Singh, 2008). The Area is of around 1667sq.kms and Population 3 lakh,of which 75% is Tribal Population (74% of total district's tribal Population) (India, 2011). Hence there is a need of identifying the unserved areas by which the mentioned issues can be addressed and solved.

This study aims to determine the accessibility of healthcare in villages within a 30-minute catchment radius. The study will identify the population threshold required for PHCs to function and assess accessibility for individuals.

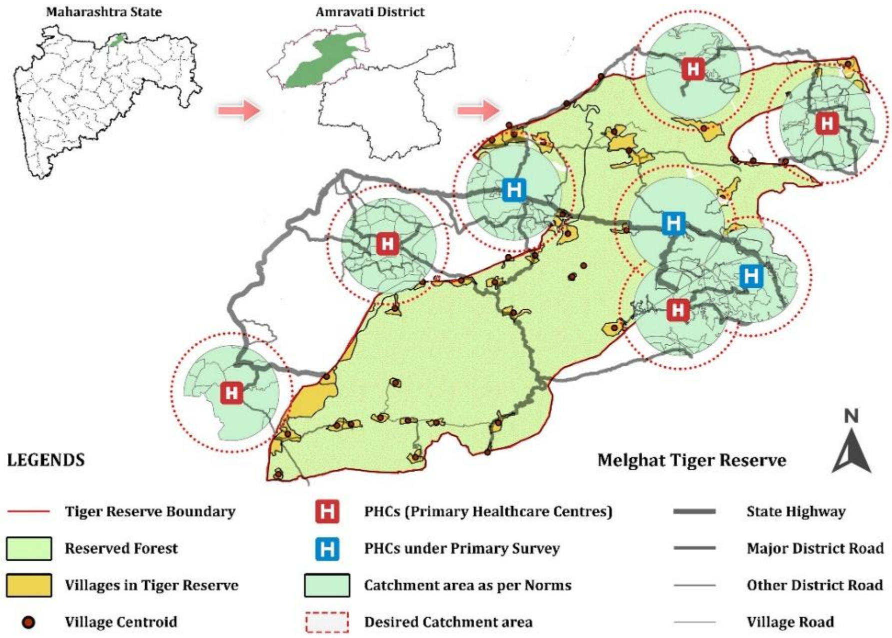


Figure1: Melghat Core Tiger Reserve map showing existing Primary Healthcare Centres and settlements within reserved area

LITERATURE REVIEW

The Indian rural healthcare infrastructure is designed as a three tire system, sub center (SC), primary health center (PHC) and community health center (CHC) (GOI, 2012). SC being the most peripheral unit, is limited with minimal healthcare facilities and therefore, people tend to turn to the PHC. Hence, PHCs has been considered as the primary unit for assessing the accessibility in this study. The degree of spatial accessibility is strongly related to social exclusion (Vadrevu, 2016). Hence, a primary survey has been conducted to assess aspects like language acceptance, Road condition, Travel cost and Medicinal affordability.

The use of GIS has provided researchers with the ability to employ varied methodological options to measure accessibility (Sherman, 2005). Traditionally, the gravity model is considered to find spatial accessibility as there is a positive correlation between healthcare quality (specialization, size) and shortest distance travel for care' (Guagliardo, 2004). The gravity model incorporates both the factors of interaction as supply and demand with distance decay function but not intuitive enough for interpretation (Luo, 2009). The major drawback of the gravity model is in the data inputs, namely, location of supply and demand (Joseph, 1984). 2SFCA is a special type of gravity model and is found to be a more appropriate tool, considering both supply and demand (Kanuganti, 2016).

2SFCA stands for two-step floating catchment area, a method used to measure and analyze spatial accessibility, particularly in the context of healthcare and urban planning. 2SFCA can be applied to various resources like healthcare facilities, schools, or job opportunities. It adapts to different travel modes and considers factors like waiting times or competition for services. The resulting maps clearly show areas with good and poor accessibility, making it easier for policymakers and researchers to understand patterns and target interventions. Compared to more complex models, 2SFCA requires less data and computational power, making it accessible to wider audiences. It doesn't account for individual differences in ability, resources, or preferences, which can affect accessibility in reality. It assumes a fixed distribution of resources and population, which may not be true in dynamic environments.

MATERIALS AND METHODS

To determine the accessibility of a village, various indicators were identified, including travel scenario, affordability, population, location, availability, and acceptance. The parameters required to calculate these indicators were identified, along with their sources, such as mode of transport, speed, distance, time, waiting time, travel cost, village population, village boundaries, medicinal cost, language acceptance, and road condition. The sources were categorized as either secondary data or primary survey data. Finally, the target audience was identified from which the required data could be obtained.

To use the 2SFCA method, the catchment area must first be specified. To achieve this, a primary survey of outpatients was conducted, and ten samples per PHC were collected to identify the source village, the distance between the source and PHC, the time taken to travel, and the mode of transport. This information was used to determine the average catchment radius and the average travel speed. Next, a desired catchment radius was identified, which is accessible within a 30-minute travel time. However, the study shows that the more outpatient survey samples are collected, the more accurate the catchment radius can be achieved. Additionally, this information helps in understanding the road conditions as per the difference between the average travel speed and the road speed specified in IRC road standards for a particular road type.

After finding out the catchment radius, the next step involves the identification of population within each settlement polygon. The population has been collected from Census Handbook 2011 for all the villages. Next the Location coordinates of existing healthcare centres were identified from secondary data collection at Zilla Parishad, Amravati. The Healthcare locations were considered as the centroids for catchment radius marking and coverage of population. Incorporating this information in GIS Database, Total population within catchment area is calculated and Healthcare to Population ratio is calculated. A primary Health Centre (PHC) should be established for every 30,000 people in general areas and every 20,000 people in hilly and tribal areas (MoHFW, 2022). The PHC's service area can only be accessed through well-connected roads. The government's prescribed rule is of having an average radial distance of 6.28 km around the PHC to cover an area of 123.09 sq. kilometres and serve 25 villages (MoHFW, 2022). It is challenging to meet these guidelines in Tribal and Hilly Regions, requiring specific catchment areas to be calculated for each region separately.

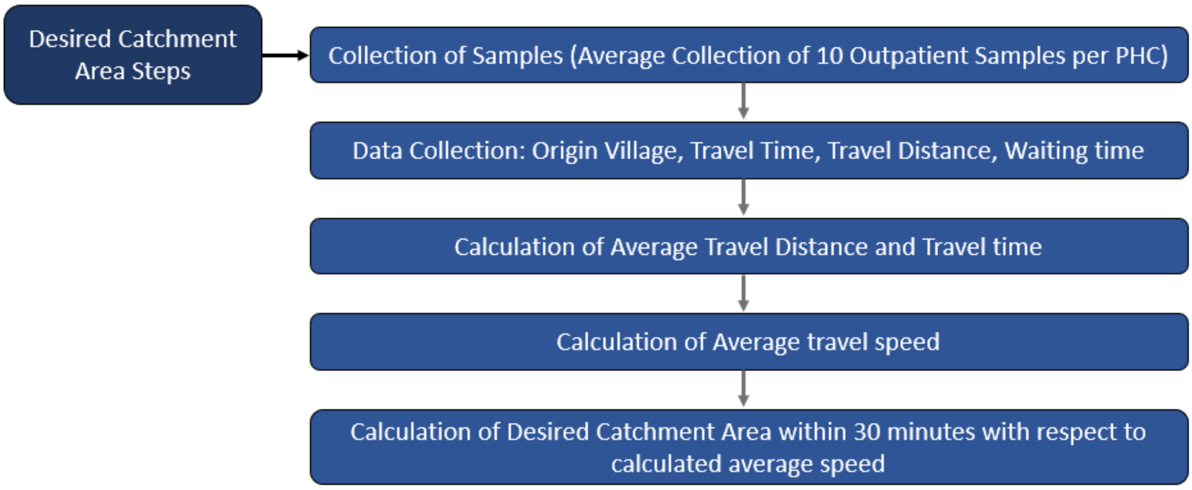
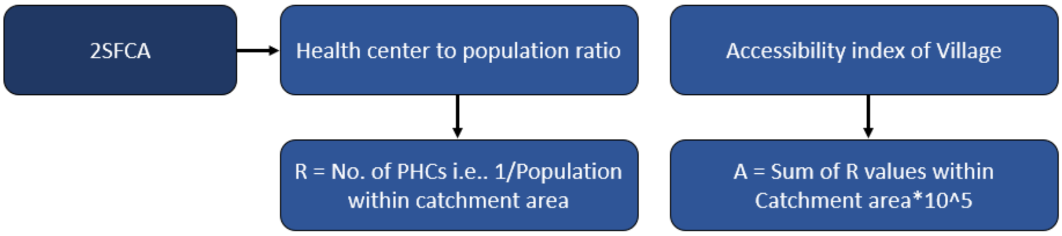


Figure 2: Steps for determining catchment area accessed within 30 minutes travel time

In the next step, we will use the Two Step Floating Catchment Area (2SFCA) method to determine the accessibility of villages. We will incorporate the catchment area data that we have obtained. First, we will calculate the Healthcare to Population ratio using the GIS database. To normalize the values, we will multiply the obtained ratio by 10^5.

To calculate the accessibility of villages, we will identify the healthcare facilities within the catchment area of each village. Then, we will sum up the individual Healthcare to Population ratios of these healthcare facilities. If we cannot identify any healthcare facilities within the catchment area, we will consider the village to be inaccessible to healthcare.



If the value of A = 0, then the village is inaccessible
If the value of A > 0, then the village is accessible

Figure3 : Steps to determine Village Accessibility Index

Other than this te questionnaire prepared for outpatients also included other questions to assessso the percentage of language acceptance by medical officials, medicinal cost, travel cost and road condition between origin and destination. This helps in finding out the other aspects of inaccessibility as well.

Result and discussion

The Outpatient survey was conducted in three primary health centers (PHCs), two of which are located in the core area, while one is situated in the buffer area. The study aimed to identify the origin location of outpatients to determine the distance between the concerned healthcare facility and the origin village. To collect data on travel time, waiting time was factored in for public transport, slope angle and corrected speed for walking, and normal travel time for private vehicles. This helped determine the difference between speed allocation of road and achieved speed on the same road.

The average catchment distance was calculated, and PHC Salona was identified as having the maximum catchment distance, indicating a different scale of approach to healthcare in hilly regions. However, the guideline of 6.8kms is not feasible in the Melghat region, as the threshold population of 20,000 cannot be fulfilled within the catchment area mentioned. Consequently, the survey concluded with a desired catchment area of 8.8kms for villages to access healthcare within 30 minutes of travel time.

Name of Healthcare centre	PHC Salona	
Parameters	Value	Units
Average Catchment Distance	30.41	Kilometres
Average Travel Time	91.5	minutes
Average Travel Speed	33.23	Kilometres/hour
Desired Travel Time	30	minutes
Desired Catchment Distance	9.88	Kilometres

Name of Healthcare centre	PHC Semadoh	
Parameters	Value	Units
Average Catchment Distance	9.23	Kilometres
Average Travel Time	34.3	minutes
Average Travel Speed	27.11	Kilometres/hour
Desired Travel Time	30	minutes
Desired Catchment Distance	8.07	Kilometres

Name of Healthcare centre	PHC Harisal	
Parameters	Value	Units
Average Catchment Distance	9.71	Kilometres
Average Travel Time	33.3	minutes
Average Travel Speed	29.15	Kilometres/hour
Desired Travel Time	30	minutes
Desired Catchment Distance	8.74	Kilometres

Average Catchement Distance Considered	8.8	Kilometres

Table 1: Calculation of Average Catchment Distance for 30 minutes travel time

After determining the catchment radius, the population of the Melghat region was included with their respective village polygons. Settlements that are concentrated in one area have more healthcare availability, even if they have a smaller population than denser settlements. The healthcare facilities with the highest population within the catchment areas will have the lowest healthcare to population ratio, while settlements with a lower population will have a higher healthcare to population ratio comparatively. Settlements with zero population are those whose populations have not been mentioned in the census handbook.

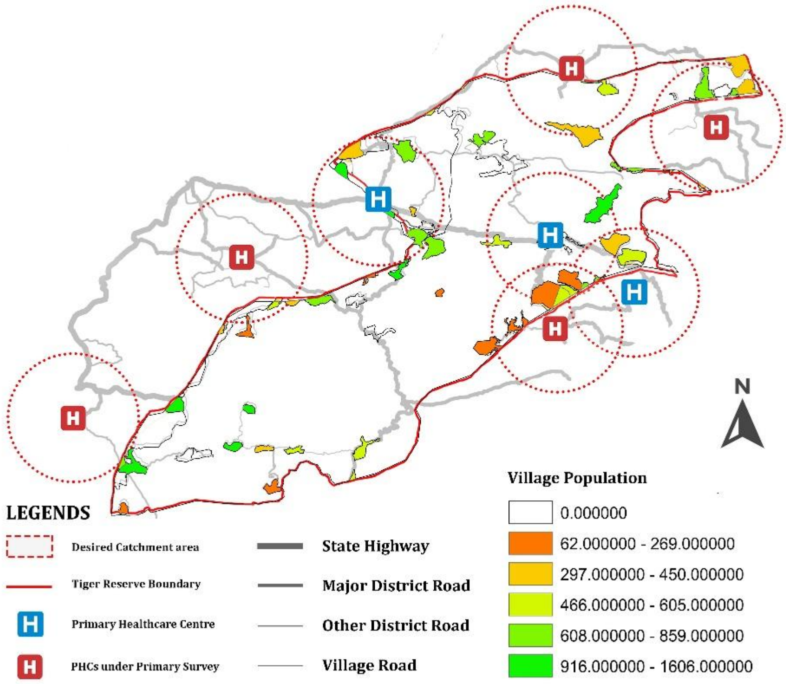


Figure 4: Population Density Map within core area settlements

The number of healthcare facilities within a particular catchment radius is divided by the population residing within the same radius. In the case of healthcare-to-population ratio, the number of healthcare facilities is considered as 1. The resulting ratio value is then normalized by multiplying it with 10^5, which allows for easier calculation of village accessibility. In this regard, the PHC Semadoh has the least population within its catchment area, resulting in the highest normalized value. This means that healthcare is conveniently available to the settlement population; however, it also affects the PHC's functionality as the minimum threshold population required for infrastructure is lacking.

Table 2: Healthcare to Population Ratio with its Normalized Value

Name of Healthcare	Population under desired catchment area	Healthcare to Population ratio	Normalized Value
PHC Semadoh	4127	0.0002423068	24.23067604
PHC Hatru	7559	0.0001322926	13.22926313
PHC Dhulghat Railway	9724	0.0001028383	10.28383381
RH Chikhaldara	16307	0.0000613234	6.132335807
PHC Katkumbh	16646	0.0000600745	6.007449237
PHC Harisal	19048	0.0000524990	5.249895002
PHC Salona	19438	0.0000514456	5.144562198
PHC Sadrabadi	30265	0.0000330415	3.304146704

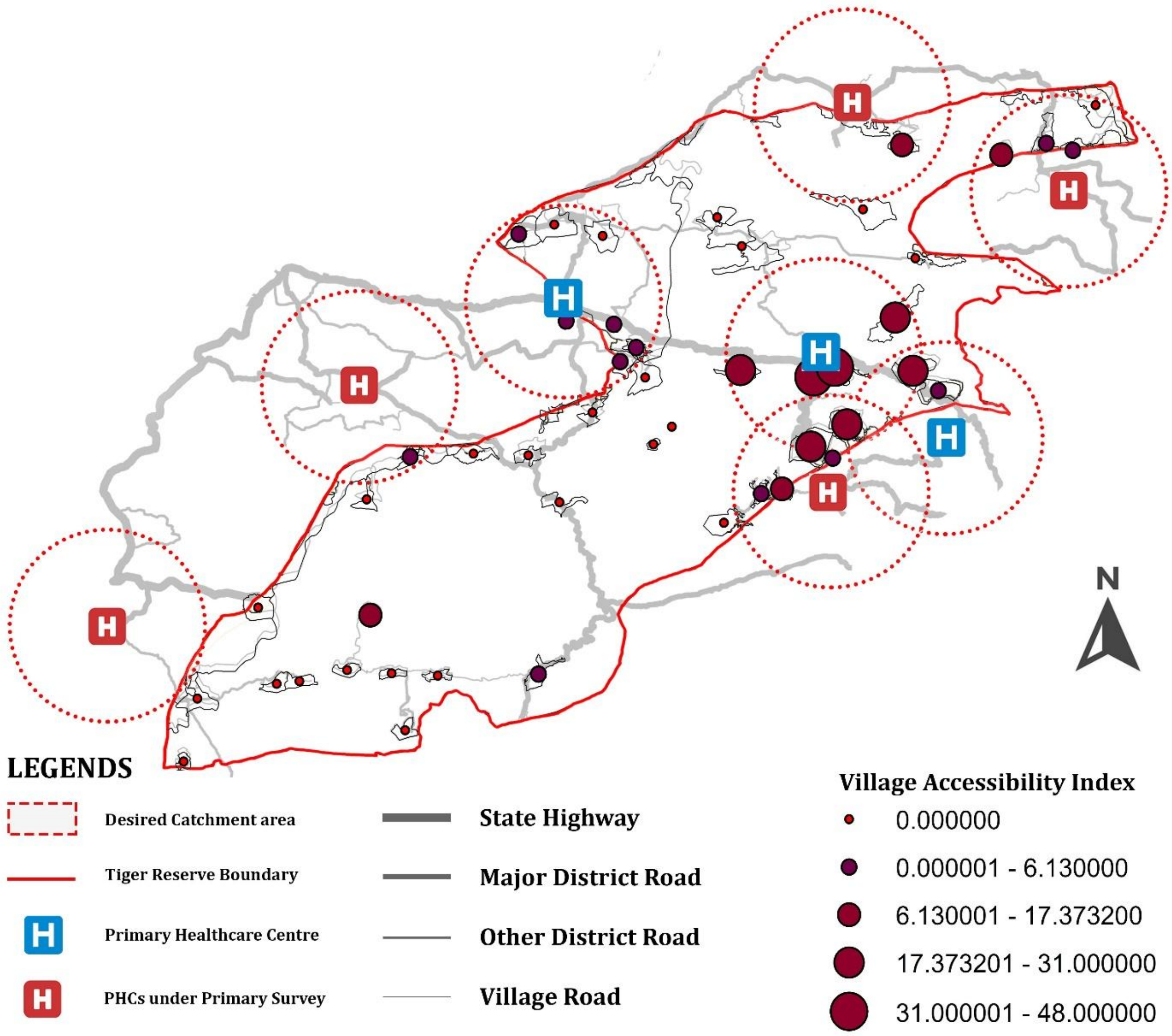


Figure 5: Village Accessibility Index of Melghat Tiger Reserve settlements

In order to determine the accessibility of healthcare facilities in a certain area, the Healthcare to Population ratio is calculated for each individual healthcare facility. Once the catchment area is identified, it is then incorporated with the village coordinates to determine the accessibility score. If a village is found to lack a healthcare centre within its catchment area, then the accessibility score is considered to be zero. The villages with an accessibility score of zero have a travel time of more than 30 minutes to reach the nearest healthcare facility, which is not recommended by the World Health Organization (WHO).

Villages with an accessibility score (as mentioned in Table:5) ranging between 0 to 5 are served by only one primary healthcare (PHC) facility, and the service provided to them is not overly allocated. However, villages with the highest accessibility score have multiple options to access healthcare facilities, which sometimes affects the threshold service population requirement of one another. This information is important in identifying the gaps in healthcare accessibility and helps in making informed decisions regarding the allocation of healthcare resources.

Out of a total of 47 settlements, only 9 have adequate access to healthcare with more than two options. 13 settlements have access to healthcare, but they require at least one Primary Health Centre (PHC) within a 30-minute travel time. Unfortunately, around 25 settlements still lack healthcare accessibility within a 30-minute travel time. As a result, it is necessary to either relocate or allocate new PHCs in these areas.

Table 3: Village Accessibility Index of all settlements within Tiger Reserve Area

Sr. No.	Village Name	Taluka	Village Accessibility Index
1	Semdoh	Chikhaldara	48.000000
2	Tetu	Chikhaldara	31.000000
3	Memna	Chikhaldara	30.500000
4	Bhawai	Chikhaldara	29.375240
5	Makhala	Chikhaldara	24.230000
6	Pili	Chikhaldara	24.230000
7	Churni	Chikhaldara	17.373200
8	Marita	Chikhaldara	13.220000
9	Bori	Chikhaldara	11.276900
10	Kameda	Chikhaldara	10.460000
11	Khatkali	Chikhaldara	6.130000
12	Pastalai	Chikhaldara	6.130000
13	Khatkali	Chikhaldara	6.130000
14	Bhiroja	Chikhaldara	5.240000
15	Mangya	Dharni	5.240000
16	Tangda	Dharni	5.240000
17	Harisal	Dharni	5.240000
18	Barugavhan	Chikhaldar	5.233410
19	Bilu	Chikhaldar	5.230000
20	Rora	Dharni	5.200000
21	Sarwarkheda	Chikhaldara	5.140000
22	Dabiya	Chikhaldara	3.030000
23	Madizadap	Chikhaldara	0.000000
24	Bortyakheda	Chikhaldara	0.000000
25	Rajpur	Chikhaldara	0.000000
26	Chunkhadi	Chikhaldara	0.000000
27	Keli	Chikhaldara	0.000000
28	Tarubanda	Chikhaldara	0.000000
29	Kund	Chikhaldara	0.000000
30	Dhakna	Chikhaldara	0.000000
31	Adhau	Chikhaldara	0.000000
32	Dolar	Chikhaldara	0.000000
33	Vairat	Chikhaldara	0.000000
34	Kelpani	Chikhaldara	0.000000
35	Dhargad	Chikhaldara	0.000000
36	Gularghat	Chikhaldara	0.000000
37	Somthana_Kh.	Chikhaldara	0.000000
38	Somthana_Bk	Chikhaldara	0.000000
39	Barukheda	Chikhaldara	0.000000
40	Amona	Chikhaldara	0.000000
41	Nagartas	Chikhaldara	0.000000
42	Charakund	Dharni	0.000000
43	Malur	Dharni	0.000000
44	Golai	Dharni	0.000000
45	RESERVE FOREST	Chikhaldara	0.000000
46	Lakhewada	Chikhaldara	0.000000
47	Koha	Chikhaldara	0.000000

The study evaluated various social parameters, including road conditions, waiting times for transportation, travel costs, medicinal costs, and language acceptance, alongside spatial accessibility. The results were obtained from a sample of 30 outpatients. Among the outpatients, only 30% expressed satisfaction with the quality of roads. Meanwhile, 43% reported moderate road conditions, which are currently under construction under the Pradhan Mantri Gram Sadak Yojana (PMGSY). In contrast, 27% of outpatients defined the road conditions as poor, citing it as a key factor that contributes to inaccessibility. Public transport, though available, is not a preferred option among the outpatients. Only 5 out of 30 patients used public transportation, with an average waiting time of 36 minutes from the scheduled time. The low frequency of travel trips makes it unpopular. The average travel cost for a round trip among the 30 outpatients was approximately 60 rupees. However, if public transportation were available, the cost would be around 20 rupees for a round trip, making it a more affordable option. All outpatients have access to free medicines, and all Primary Health Centers (PHCs) have been equipped with two counselors each to facilitate language conversation between the patients and medical officers, as per the norms.

CONCLUSION

This study aimed to improve healthcare accessibility in rural tribal areas using the 2SFCA model. This is a powerful gravity model that is based on a GIS platform. The researchers used the model to determine the area of influence of each health center and measure the accessibility level of each village. The results were presented on a GIS map, which made it easy for policymakers to identify areas with poor accessibility, also known as "dark zones". By identifying these areas, policymakers can take appropriate measures to improve infrastructure, such as building new roads and identifying optimal locations for new health centers. The study is expected to have a significant impact on the health and well-being of people living in rural tribal areas by improving their access to healthcare services. This method is relatively easy to understand and implement compared to other accessibility measurement methods. It can be adapted to different contexts by incorporating various factors like travel time, distance decay, and resource supply/demand. However, its accuracy can be impacted by data quality, chosen parameters, and the complexity of the analyzed environment.

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Space Harmonization in Internal Architecture - An Interplay Between Tangible Elements for A Holistic Design

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Abstract— Harmonization within architectural components is a primary factor that governs all aspects of space formulation. Apart from minimal functionality, to implement the physical, emotional, and spiritual attributes of humans, the study aims to address the users perceptions of harmony and disharmony in architectural space. It helps to explore the concept of spatial design internally, examining how the alignment and design of interior spaces affect inhabitants' experiences and overall well-being. This paper involves organizing tangible factors and the interplay between design elements—form, color, texture, and arrangement of components—to execute cohesive and unified design. Based on case studies and design principles analysis, the research aims to interpret the psychological and aesthetic magnitude of spatial layout, assess feasible inputs to create internal spaces for better functionality and well-being, and achieve a holistic approach and tranquillity within space.

Keywords: Harmony, Disharmony, Perception, Spatial Design

INTRODUCTION

Harmonizing space means the systematic proportion and implementation of certain tangible factors to provide environments apart from being functional but has also aesthetically and emotionally sound. In internal architecture and interior design, the significance of holistic spatial design has become deliberately rising, as professionals in both architecture and interior design, the strive to create interiors that support well-being, productivity, and comfort. This interdependency between tangible elements—viz, layout, materials, lighting, textures, and furnishings—becomes the pillar of a cohesive design methodology that concerns both the feasible and functional components of space.

The emphasis of spatial harmony is the comprehension of architecture, being not just a collection of individual elements, but a solidified strategy where every aspects matters. The linkage between solid and void, the contrast of light and shadow, and the juxtaposition of materials are all critical to how users perceive and interact with a space. Targeting this goal, a schematic system that understands both architectural styles, forms and functions, while also design principles and elements.

This research analyzes how the implementation of these tangible elements influence the holistic internal architectural design. It investigates the schematic procedures of making superb interplay among the exterior and interior features and structural elements, endorsing that the entire design enhances a sense of unity and harmony. By examining few case studies with pros and cons, the study tends to disclose factors and strategies that can impact in a better way, the future design in creating spatial planning that not only provide functionality and services but also foster user experience.

Need of research/study

- Negative health consequences of neglecting multisensory stimulation- It can have a range of negative health consequences, particularly because humans rely on multiple senses to interpret and interact with their surroundings. When architectural spaces are designed with limited consideration for the full spectrum of sensory experiences—beyond just the visual—they can negatively affect physical, mental, and emotional well-being.

- Designing for the modular mind - It implies creating surroundings that nourish the specific but also the interconnected factors of cognitive behaviour and user experience. Addressing the brain's modular nature, architects and designers can create spaces that upgrade cognitive function, physical, emotional and sensory engagement.
- Architectural design for each of the senses - Architecture is primarily visual, but when planners and designers tackle with all the senses, it gives space that is cozier, more homely, more intuitive, and more instinctively sound.
- The look of architecture - It signifies the aesthetic qualities and visual perception of a structure or space, which are predominantly the primary aspects that human perceive. It integrates form, style, texture, color, and unity that how a structure is visually interpreted. Though architecture is a multisensory experience, the visual aspect—a building profile—plays a key factor in defining its identity, image, and relationship to its surrounding context.
- The sound of space - Acoustic experience within architecture, is a critical but often overlooked aspect of design that significantly impacts how we perceive and interact with environments. Sound shapes our emotional and psychological responses to spaces, influencing feelings of comfort, productivity, relaxation, or even tension. Architecture is not just about what we see or touch, but also about what we hear, making acoustics a vital element in creating holistic, functional, and enriching environments.
- Designing for "the eyes of the skin"- Creating architecture that is tactile, sensory-rich, and attuned to how the body interacts with the built environment, leading to spaces that feel more human-centered, intimate, and emotionally resonant. It play a profound role in shaping our experience of space. The chemical senses are deeply intertwined with memory, emotion, and physical well-being, making them powerful tools in designing architecture that resonates on a deeper, more subconscious level.
- An architecture of the chemical senses - Considers how the design of spaces can influence and be influenced by smell and taste, creating environments that evoke sensory richness, enhance well-being, and promote emotional and cultural connections.
- Sick building syndrome - A state in which residents encounter with minor health issues or discomfort that is probably due to time spent inside a specific building but where no specific illness or cause can be identified. Symptoms could be- headaches, eye irritation, respiratory issues, dizziness, fatigue, and skin irritation. Generally they recede after the habitant goes outdoor signifying that the discomfort is impacted by the building.
- "An architecture of the seven senses"? - It extends beyond the commonly known five senses—sight, sound, touch, taste, and smell—adding two more: proprioception (the sense of body position and movement) and thermoception (the sense of temperature). Together, these senses form a comprehensive framework for designing spaces that are not only visually appealing but also deeply engaging on a physical and emotional level.

Figure. 1: High and Low Spaces for Special Harmony

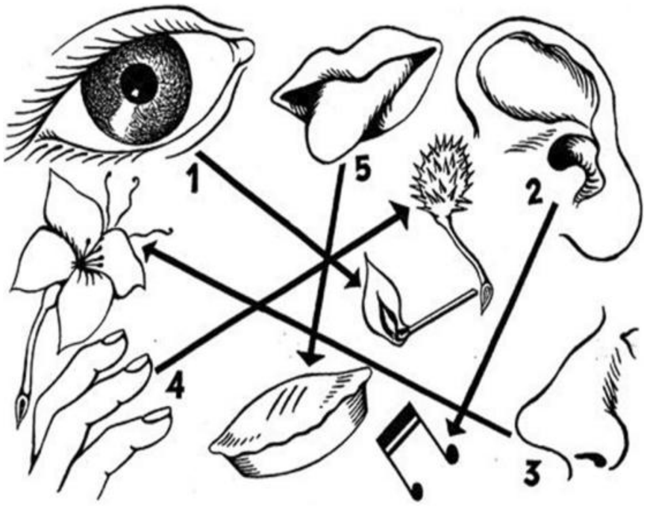

Figure . 2: Our sense

Aims/Objectives of the research

- To assess the methodology of the design process in interior architecture with respect to design principles and elements.
- To study the correlation between tangible factors and how to create harmony amongst them in obtaining a unified design.
- To conduct primary and secondary research with a view to identifying how it affects users' spatial experience.
- To perform a critical overview of spatial layout with regard to users' experiences and organize them within the theory-practice relationship to achieve both physical and mental comfort.

Scope of work

Literature Study: Explore existing research, theories, and design principles related to space harmonization in internal architecture.

Analysis of elements: Investigate the impact of tangible elements, including materials, lighting, and spatial layout, on the overall design harmony.

Case Studies: Examine successful architectural projects that exemplify effective interplay of tangible elements for holistic design.

User Experience Review: Explore the psychological and emotional responses of users within harmonized internal spaces

Formulating Methodology: Establish a research framework for evaluating and implementing space harmonization principles across various types of internal environments

Assessing feasibility: Evaluate the adaptability of space harmonization principles across different types of internal spaces.

Limitations

The research is oriented towards users perspectives and confined to specific cultural aspects, so the study is exclusively for Aizawl residents.

User groups study was limited to students and working adults.

The project emphasized on the emotional and psychological health to a greater extent thus, physical well being won't be further contemplated.

Cost and financial estimation are not taken into consideration.

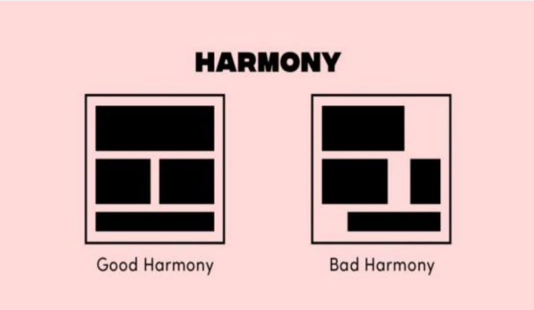

Figure . 3: Harmoney principles

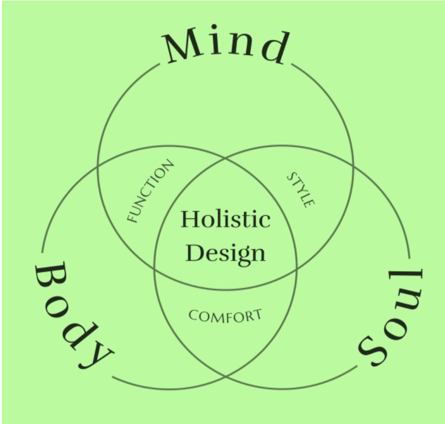

Figure no. 4: Holistic design factors

Understanding Harmony

Harmony in Architecture' is an exploration of possible intersections between architecture and interaction design, in order to check possible levels of application of interaction design in architecture. Interaction design is about designing interactions that are visible, felt and experienced. Where as architecture is about planning and designing space where different interactions take place, our goal is to plan seemingly invisible interactions between inhabitants, nature, space.

Holistic design and contributing factors

Spatial design principles

It is the design of human environments, particularly interior environments. Working from the inside out, spatial designers think about how spaces feel, how they are organised and how they might enrich the lives of those experiencing them.

Spatial design helps designers understand how architecture weaves the overall experience of a place for the users. For architects and interior designers, the implementation of spatial design lies in spatial arrangement and planning. In this article, we will further look into the aspects of spatial design and how designers can create experiential spaces for users.

Tangible elements of harmony in space

Figure . 5: Elements of harmony

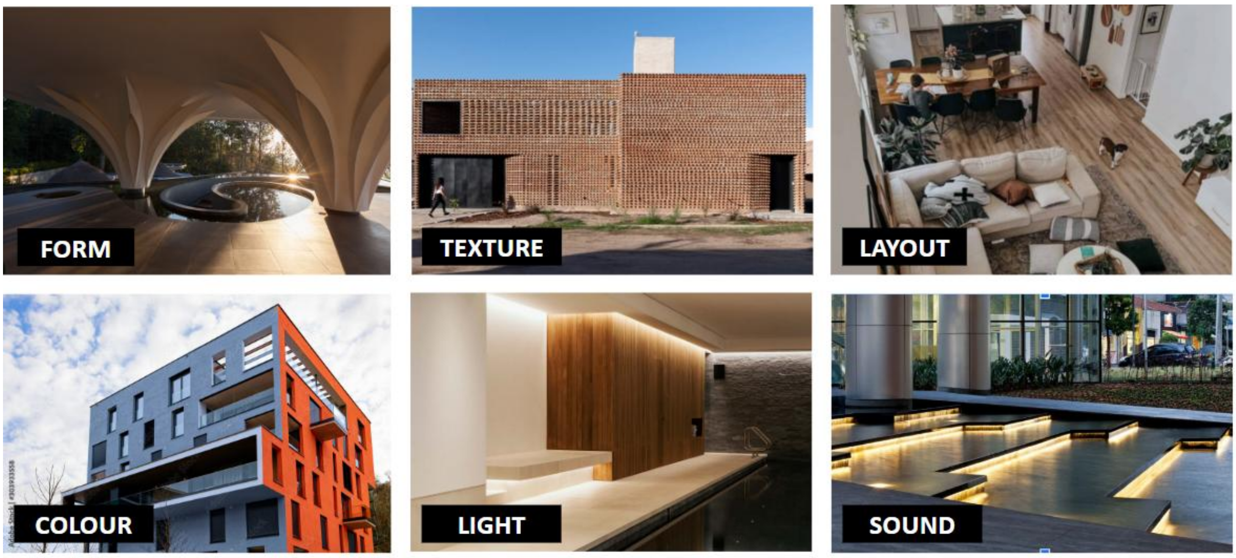

Figure 6: Tangible factors

Table No. 1&2 Case study - Current scenario of mental health in Mizoram

Sl. No.		Components	Apr '19	May'19	Jun'19	Jul'19	Aug'19	Sep'19
	Early detection and treatment of mentally ill patients							
1.	a	**OPD**	1055	1346	1194	1250	1139	1386
	b	**IPD**	137	141	134	160	112	150
	Outreach for increasing awareness and reducing stigma related to Mental Health Problems							
2.	a	No. of Free Clinic cum Awareness	21	17	14	20	11	28
	b	No. of patients seen in Free Clinic	1417	1354	1118	1226	793	2138
	c	No. of Awareness	18	25	23	24	18	25
	d	No. of participants in Awareness Prog	1920	1781	1571	1534	1880	2625
	e	No. of Phone calls in Crisis/ Suicide Helpline	19	44	27	31	29	42
		No.of refer	8	4	4	6	3	4

Sl. No.		Components	Oct'19	Nov'19	Dec'19	Jan '20	Feb'20	Mar'20
1.	**Early detection and treatment of mentally ill patients**							
	a	**OPD**	1373	1197	1057	1450	1446	995
	b	**IPD**	167	151	117	153	143	157
2.	**Outreach for increasing awareness and reducing stigma related to Mental Health Problems**							
	a	No. of Free Clinic cum Awareness	29	17	29	24	21	14
	b	No. of patients seen in Free Clinic	6428	1426	1640	1781	1170	1127
	c	No. of Awareness	28	47	18	15	23	2
	d	No. of participants in Awareness Prog	1856	3473	716	955	1168	116
	e	No. of Phone calls in Crisis/ Suicide Helpline	36	31	37	32	30	268
		No.of refer	6	3	2	10	8	12

Table No. 3 Total Cases

Grand Total:-

OPD	**: 14888**
IPD	**: 1722**
No. of Free Clinic cum Awareness	**: 245**
No. of patients seen in Free Clinic	**: 21618**
No. of Awareness	**: 266**
No. of participants in Awareness Prog	**: 19595**
No. of Phone calls in Crisis/ Suicide Helpline	**: 626**
No. of refer	**: 70**

Professional relations of both students and working adults with their classmates, colleagues, and management may lead to his/her better mental health which is predominantly affected by the harmony or disharmony of all the aforementioned

influence their potentials. Space provided for their studies and works plays an important role in the learning process as well as working performance. If they are not mentally healthy then the negative tangible factors and the overall room layout where he resides.

Therefore the quality, competence, character, and effectiveness are the most significant factors which

impact will be upon their inmates, friends and colleagues.

Table No. 4: Metal Health of Students

Mental Health of Higher Secondary Students in Different Streams of Study

Stream of Study	Total Number of Students	Mean Score	Percentage of Mentally Healthy	Percentage of Not Mentally Healthy
Science	10	168.4	71	29
Commerce	10	168.4	68	32
Arts	16	162.4	62	38

Table No. 5: Working adults user group

	Gender		Management		Total
	Male	Female	Government	Private	
Working adults who scored below 150	19 (31.15%)	23 (26.14%)	25 (30.86)	17 (25%)	42 (28.19%)
Working adults who scored above 150	42 (68.85%)	65 (73.86%)	56 (69.14%)	51 (75%)	107 (71.81%)
Total	61	88	81	68	149

Identification of tangible factors - Online Survey

Can users notice these factors in a built environment even though they may not be architects or designers

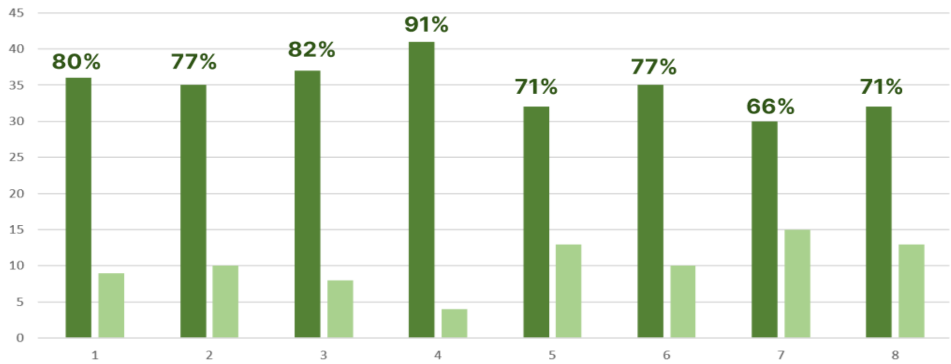

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Figure 7: Results from survey

Overwhelmingly users were able to identify subtle elements that create harmony in spaces on the survey

Live Case study - Previous environment

Figure 8: Private hostel in Aizawl

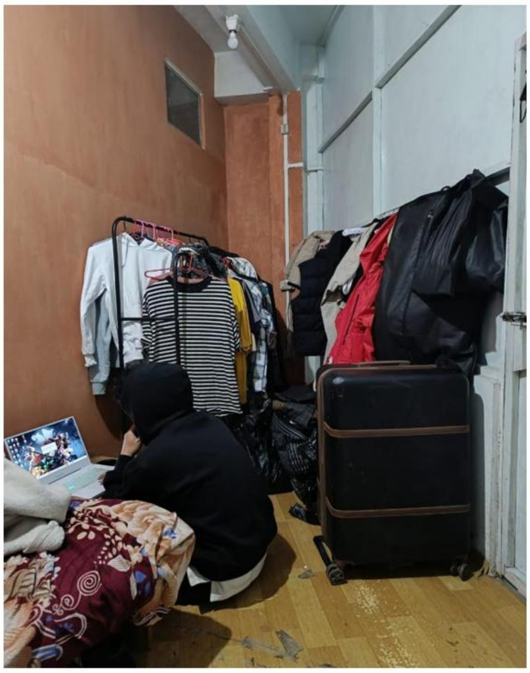

Figure 9: Rented flat

Issues raised by tenant

Layout: Layout of the rooms is very improperly done creating confusion at times

Light: Insufficient openings creates an environment with very low light

Colour: Monotone and bland colours affects user enjoyment of the environment

Texture: Quality of partition walls had an effect of the texture comfort factor of the rooms

Live Case study - New environment

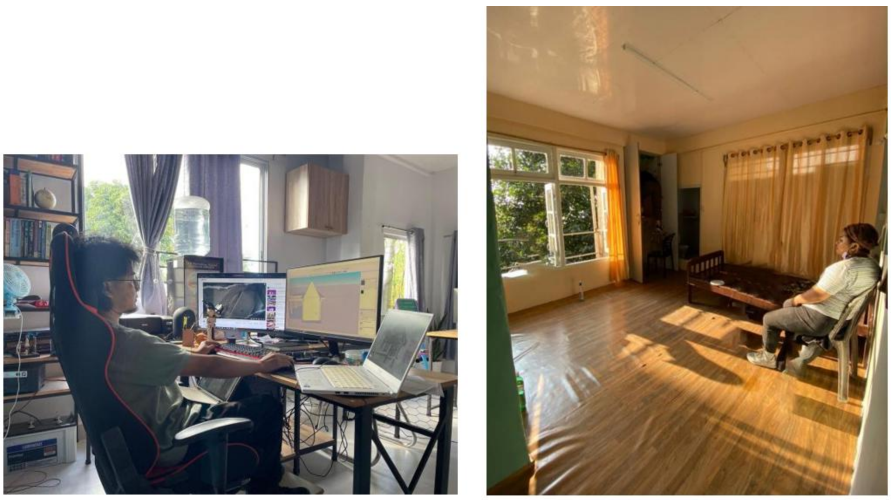

Figure 10: New rented flat in Aizawl

Experiences from new Environment

Light: Warm lighting creates a more comfortable and relaxed atmosphere and is generally softer on the eyes.

Colour: Comparatively,a more vibrant and varied colors enhance user enjoyment of the environment.

Sound: The soundscape of a place greatly contributes to its ambience and mood. Harmonious sounds like gentle rushing of leaves can create a tranquil environment.

Layout: The room is more spacious and makes it possible for a better layout which eliminates potential confusion.

Does Harmony improve life of users? - Online/Case Study

Figure 11: Study on the possible impact of environment

Positive Harmonial experiences can also have restorative effects, for example through stress recovery and attention restoration.

The other dimension is instoration, where spaces can improve mental health by encouraging physical activity and facilitating social cohesion.

Our case studies highlight the transformative impact of harmony on the users. The positive adjustments highlight the value of deliberate design in creating spaces that meet both practical and emotional demands, resulting in a more pleasant and rewarding experience.

Assessing Feasibility/Opportunities

- Basic interview to identify background, routine, interests, habits, and culture of our user/client.
- Interviewing users to find out their pain points which may be inflicted mentally through physical discomfort.
- Researching opportunities of which tangible factors are viable. Testing which element or the combinations of elements would be most effective.
- Availability of components required for execution of a holistic design.

Planning & implementation

User centric implementation could be most effective, it may be done through pre- determined testing.

Environment centric which could be easier and cheaper to implement

CONCLUSIONS

What is the significance of spatial design in the life of an architect or interior designer?

When it comes to designing a space, architects and interior designers have certain expectations for themselves. As a result, at times, it is their imagination that first defines the form and shape of the place. Moreover, when these imaginations are put forward, they often miss the purpose for which they are built. But nowadays, as we see, more efforts are made by designers to design human-centric designs.

Thus, the concept of spatial design and its aspects will help them further elevate the experience of space. The concept directs one to focus on the user and their needs and requirements for the space. Both tangible and intangible aspects of the building fulfil these needs. Hence, spatial design is a concept that helps one craft an experiential space that gives the user various living opportunities within the building.

From the above observations, we can conclude that building with the concept of spatial design means to design user's intended experience of the place. How can a designer always keep in mind the user needs and also elevate different experiences in the building?

CONFLICTS OF INTEREST

No conflicts of interest were declared by the authors.

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Parametric Sustainability: Optimizing Building Performance

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Abstract— Parametric sustainability is an innovative approach to sustainable design and architecture that integrates the principles of parametric design with sustainability objectives. The aim of this study to investigate the concept of parametric sustainability and its application in optimizing building performance. The need to create sustainable solutions for the built environment is becoming increasingly urgent, as global environmental concerns increase. Parametric design, with its ability to produce and assess multiple design iterations, presents a promising way to improve the sustainability of a building's performance. The idea of parametric sustainability, guiding principles, and applications in the realm of architecture and building design were examined in this study. However, there are currently few design possibilities that have been investigated and few performance evaluation techniques that are available to designers during the early stages of design. In order to help designers assess daylighting and energy efficiency, produce optimal design solutions, and comprehend the connection between design factors and performance metrics, this research suggests a new process for optimising building performance. The suggested approach to performance optimization makes use of a number of tools and technologies, including generative algorithms, parametric design, and building simulation tools such as Rhino3d (Version 7), Grasshopper Tools including Ladybug-1.50, Honeybee-1.50 and Climate Studio (Version 1.9). This approach uses parametric design to thoroughly study many architectural design options, building performance is assessed by modelling and simulation of daylighting, radiation and energy, design choices with the best energy and daylighting performance are found using generative algorithms. A case study was carried out to test and verify the efficacy of the building performance optimization. Total three optimization processes: daylighting, energy and radiation is carried out. This approach effectively demonstrated its capacity to adjust to different design settings and produce design solutions with appreciable performance improvements through the optimization stages. This performance optimization analysis of three optimization cases also revealed general building performance. These findings can also be recommended further to provide design guidelines for sustainable buildings. This study offers architects, designers, and other stakeholders a road map for maximising building performance by utilising the possibilities of parametric design, adding to the continuing conversation on sustainable architecture.

Keywords: Parametric Design, Sustainability; Building Performance; Computational tools; Optimization.

INTRODUCTION

In the face of intensifying environmental problems worldwide, the built environment is at a turning point. The architectural and construction industries are challenged with reevaluating their practises to create buildings that are not only aesthetically pleasing but also environmentally responsible and energy-efficient due to growing concerns about climate change, resource depletion, and the necessity to reduce carbon

emissions. According to many research the early design stage is the most important part in achieving sustainable building design and performance (Li et al., 2018). Modern architectural and design techniques like parametric design have shown promise for improving building performance through sustainability (Zhang et al., 2020). More than 60% of the world's population is anticipated to reside in cities (World Urbanization Prospects The 2014 Revision Methodology, 2017). Under the 17 Sustainable Development Goals (SDGs) framework, urbanization increases the potential for sustainable development (SD) through increasing access to public and commercial services, public education, and employment opportunities.

Figure 1: Three Pillars of Sustainability

All design elements and their dimensions, such as location, area, orientation, shape, solar radiation, and so forth, can be thought of as parameters in a general architectural design (Eltaweel & SU, 2017a). Parametric design with its utilization of generative algorithms, design variables, and performance evaluation metrics, offers a unique framework for reimagining the design process (Stavric & Marina, 2011a).

By using computational tools such as Rhino-Grasshopper and Revit-Dynamo to generate and assess numerous design iterations, architects and designers can explore innovative solutions that reduce the environmental footprint of buildings while enhancing their overall performance. This study investigated the idea of parametric sustainability, a novel way to combine sustainability goals with parametric design principles, and how it might change the built environment.

LITERATURE REVIEW

Parametric Design

In architectural design practice and research, parametric design is becoming more and more popular. The parametric design approach defines and adjusts, via the use of parameters and algorithms, the relationships between various design features (Caetano et al., 2020). In parametric design, parameters serve as variables that can be changed to provide different design outcomes. These features could be material, geometric, environmental, or possess additional architectural features (Stavric & Marina, 2011b). Designers can explore a wide range of design options by varying these variables, which is particularly useful when maximizing a building's sustainability in terms of performance. Recently, parametric design has gained a lot of interest due to its potential to maximize building performance and sustainability. This section will look at parametric design, its history, and its application to architecture (Stavric & Marina, 2011c).

Thanks to parametric design, architects may now experiment and work with complex forms and structures that were previously challenging to plan and construct. Its versatility makes it a helpful tool for optimizing building efficiency, with sustainability being the main objective (Stavric & Marina, 2011c).

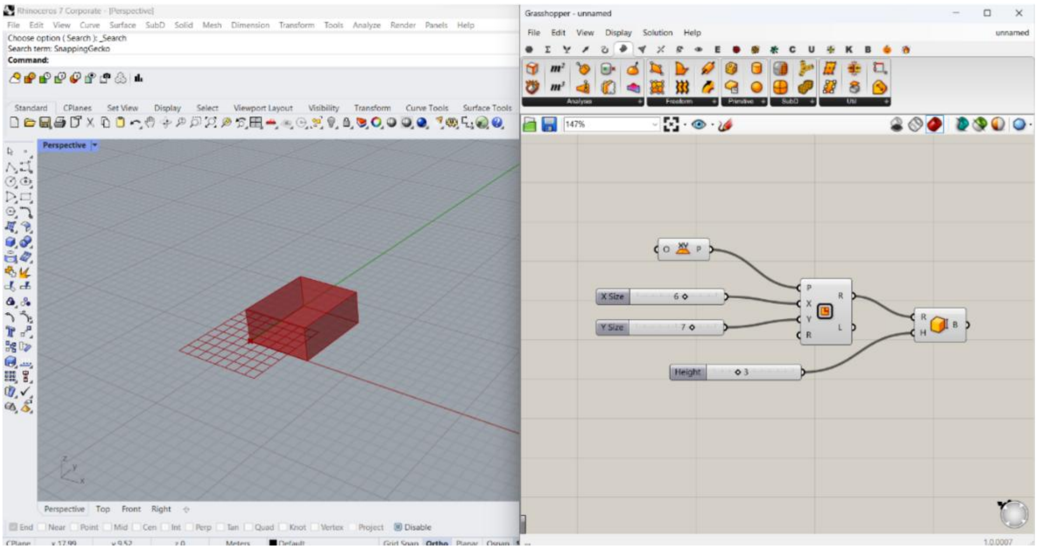

Figure 2: Parametric Design

Parametric Design Principles

Parametric design operates based on a set of core principles:

Algorithmic Modelling: The core of parametric design is algorithmic modelling. In order to create and modify the design elements, mathematical techniques are used. These algorithms might be anything from intricate scripts to basic mathematical formulas. Using algorithms, it is easier to create highly customized, complex designs that adjust to different inputs (Caetano et al., 2020).

Generative Design: A subset of parametric design called "generative design" concentrates on using optimization methods to create designs. Based on predetermined criteria, these algorithms investigate multiple design iterations and offer the designer the most effective options. Building sustainability can be greatly increased by using generative design to optimize aspects like as material utilization, energy efficiency, and more (Stavric & Marina, 2011b).

Scripting: Scripting languages like Python and Visual Basic for Applications (VBA) are commonly used in parametric design. Designers write scripts to automate design processes, perform complex calculations, and control design variations. Scripting empowers designers to create highly sophisticated and adaptive design systems (Caetano et al., 2020).

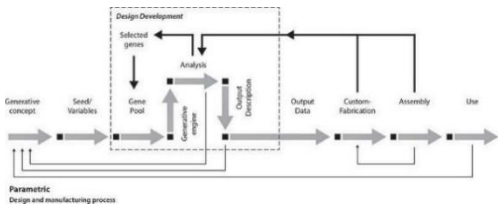

Figure 3: Parametric Design Process

Parametric Design Software

A variety of software tools have been created to assist parametric design ideas, which are gaining popularity in the domains of engineering and architecture. (Eltaweel & SU, 2017a) reviewed that the most popular programmes are 3D MAX, 3D Maya, Revit, Grasshopper, and Dynamo, and that the first parametric design software was developed in 2008(Schnabel, 2007). Architects and designers can easily generate and modify parametric models with the help of these software tools. Among the programmes for parametric design that are most frequently used are:

Grasshopper: A popular visual programming language and plugin for Rhinoceros 3D is called Grasshopper. Because of its user-friendly graphical interface, which makes it easy to develop sophisticated algorithms and parametric models, it is a favorite option among architects and designers. The building geometry development, mechanical engineering, environmental analysis, and building structure are among the domains in which the plugins are meant to be used. HoneyBee and ladybugs are usable by a larger spectrum of users because to this functionality (Stavric&Marina,2011b).

Rhinoceros 3D: With its Grasshopper plugin, Rhinoceros 3D, sometimes known as Rhino, is a flexible 3D modelling programme that facilitates parametric design. It is renowned for its adaptability and capacity to produce intricate 3D forms that react quickly to adjustments made to the design specifications (Stavric & Marina, 2011b).

Dynamo: An open-source visual programming platform called Dynamo was created especially for building information modelling (BIM) applications like Autodesk Revit. It improves the integration of parametric design with the design and construction process by allowing engineers and architects to develop models directly within the BIM environment (Stavric & Marina, 2011b).

Sustainable Design

Often called green design or eco-design, sustainable design is a fundamental change in how we think about engineering, architecture, and the built environment. It is an answer to the urgent problems of resource scarcity, climate change, and the requirement for a more accountable and restorative interaction between man-made structures and the natural world (Polytechnica & Eng, 2003).

The process of designing structures and environments that balance the environment, enhance occupant well-being, and support long-term social and economic sustainability is known as sustainable design (Polytechnica & Eng, 2003). It highlights a dedication to reducing the built environment's detrimental effects on the environment while optimising its beneficial effects on society (Polytechnica & Eng, 2003).

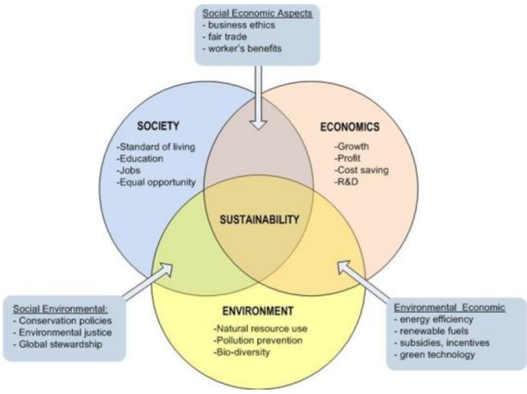

Figure 4: Interplay of the environmental, economic, and social aspects of sustainable development

Significance of Sustainable Design :

Environmental Responsibility: Climate change, environmental pollution, and resource depletion have all been exacerbated by unsustainable building techniques. Sustainable design aims to minimise waste and resource consumption in order to lower the built environment's carbon footprint (Polytechnica & Eng, 2003).

Social Well-Being: Human health and well-being are significantly impacted by the built environment. Creating environments that improve people's comfort, safety, and quality of life is a top priority in sustainable design. Its goal is to improve the health and well-being of building residents (Polytechnica & Eng, 2003).

Economic Viability: Sustainable design is not just an ethical choice but a pragmatic one. It offers long-term economic benefits by reducing operational costs, conserving resources, and ensuring resilience in the face of changing environmental conditions (Polytechnica & Eng, 2003).

Building and Daylight - Benefits of Daylight

Daylighting is a crucial component of architectural design since it affects a building's sustainability, usability, and beauty. Daylighting is the process of designing a structure with daylighting in mind. It improves tenant comfort and well-being while also supporting energy efficiency and environmental sustainability. A well-planned daylighting environment can raise building energy efficiency and enhance occupant productivity and wellness (Fang et al., 2017).

Table 1: Default Values for Surface Reflectance

Surface Type	Reflectance
Wall or Vertical Internal Surfaces	50%
Ceiling	70%
Floor	20%
Furniture (permanent)	50%

Table 2: Daylight Requirement

Building Category	Percentage of above grade floor area meeting the UDI requirement		
	ECBC	ECBC+	SuperECBC
Business, Educationa	40%	50%	60%
No Star Hotel Star Hotel Healthcare	30%	40%	50%
Resort	45%	55%	65%
Shopping Complex	10%	15%	20%
Assembly*	Exempted		

Table 3: Maximum Allowed EPI Ratios (Composite Climate)

Building Type			
	ECBC	ECBC+	Super ECBC
Hotel	1	0.91	0.81
Resort	1	0.88	0.76
Hospital	1	0.85	0.77
Outpatient	1	0.85	0.75
Assembly	1	0.86	0.77
Office (Regular Use)	1	0.86	0.78
Office (24Hours)	1	0.88	0.76
Schools and University	1	0.77	0.66
Open Gallery Mall	1	0.85	0.76
Shopping Mall	1	0.86	0.74
Super Market	1	0.81	0.7
Strip Retail	1	0.82	0.68

Daylight Simulation

Because daylight simulation makes it possible for designers, engineers, and architects to anticipate and maximize the distribution of natural light in a room, it is an essential component of building design and performance analysis. It has a major impact on improving energy efficiency, sustainable design, and occupant comfort. This study discusses the value of simulating daylight and presents some of the most important software tools for the job (Eltaweel & SU, 2017b).

Building and Energy

Buildings and energy have a substantial and intricate interaction that involves both energy consumption and conservation. Buildings have a significant influence on the amount of energy used worldwide, thus understanding this relationship is crucial to achieving sustainability and energy efficiency goals. Here, we examine the numerous facets of the relationship between energy and buildings (Matrawy et al., 2015).

Energy Simulation

Energy simulation is a computational method used to model and analyze the energy consumption and performance of buildings. It is also known as building energy simulation or building performance simulation. It is essential to the planning and functioning of buildings because it enables engineers, architects, and building owners to make well-informed choices regarding sustainability, comfort, and energy efficiency. In this article, we examine the idea of energy simulation, its significance, and its uses (E N E R G Y, 2017).

Building And Radiation

Building design is greatly influenced by radiation, which can have both beneficial and detrimental effects on people's health. It is essential for architects, engineers, and other building professionals to comprehend the various types of radiation, their sources, and how they affect structures and their occupants. Here, we examine how radiation affects building design and what that means for people's health (Tchorz-Trzeciakiewicz & Olszewski, 2019).

Radiation Simulation

The term "radiation simulation" describes the application of computer-based modelling and simulation methods for the purpose of forecasting, analyzing, and visualizing radiation behavior under different conditions. It is an invaluable resource for comprehending how radiation affects various systems, including the movement of radioactive materials, the behavior of solar radiation in building design, and the spread of EMFs (Duan et al., 2016).

METHOD

Conceptual Framework

Schematic design, a crucial early stage of architectural design, incorporates the suggested building performance optimization procedure (Figure5). Architects create early building design concepts, which include study drawings that show the spatial relationships, size, and shape of the design, when they have a firm understanding of the project goals and criteria. Without sacrificing the original building design concept, the goal of the building performance optimization process is to offer designers optimum design options. The design will proceed to the following design stages if the suggested design solutions satisfy the performance target and other design requirements. If it's not good enough, the original design concept can be changed, and this optimization process can be carried out several times, until a desired design is achieved.

The framework's four primary parts are modelling of daylight and energy, simulation and building performance metrics, optimization, and parametric building design. The intention is to automate the process of creating building designs, performance simulations, and optimizations while integrating the four components in a seamless manner. The process of defining building geometry using design parameters and functions is known as parametric design. When design parameters are changed, design alternatives are produced. The programmes Grasshopper and Rhino are used for parametric modelling.

In the process of energy and daylight modelling, the parametric model is assigned with particular building data, such as geometry, nearby information, kinds and materials of construction, loads, occupancy, and operating schedules. The tools for energy modelling are the ladybug and honeybee. Honeybee is in charge of managing and displaying simulation and meteorological data, while Ladybug is in charge of modelling energy and daylighting. Ladybug will generate an idf file for EnergyPlus's energy simulation and a rad file for Radiance's daylight simulation. After the simulation, Ladybug imports the simulation result file back into Grasshopper to retrieve the energy and daylight performance metrics.

Two kinds of input are required for the optimization process: variables and fitness functions. Variables are the building design parameters in Grasshopper that can regulate the building geometry in building performance optimization. The energy or daylight performance measurements that the simulation engine computes make up the fitness function. The minimum or maximum value of the performance parameter, such as the least energy load or the maximum Udi, is the fitness function for single objective optimization. Next, in order to produce new design alternatives that improve performance, a generative algorithm is utilised to investigate the relationship between design parameters and performance measures.

Different tools are needed for each component; Figure 6 illustrates the tool's organisational structure. Rhino a 3D NURBS modelling tool. Grasshopper is a Rhino plug-in that offers a parametric modelling platform that combines features from Rhino with those from other add-on applications. Grasshopper plug-ins include Ladybug, Honeybee, Galapagos and Octopus. Two modelling tools for energy and daylighting are Ladybug and Honeybee. They are linked to the daylighting and energy simulation engines, Radiance and EnergyPlus. Octopus and Galapagos are tools for optimization. Octopus is used for multi-objective optimization, while Galapagos is used for single-objective optimization.

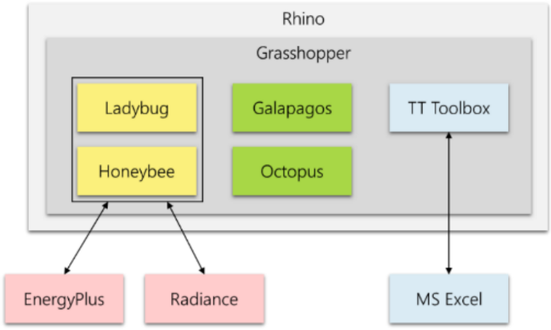

Figure 5: Structure of Optimization Tool

Research Framework

The whole research approach and methodology is shown in Figure 7. There are four primary actions. creation of an energy and daylight model for four optimization scenarios is the second phase.

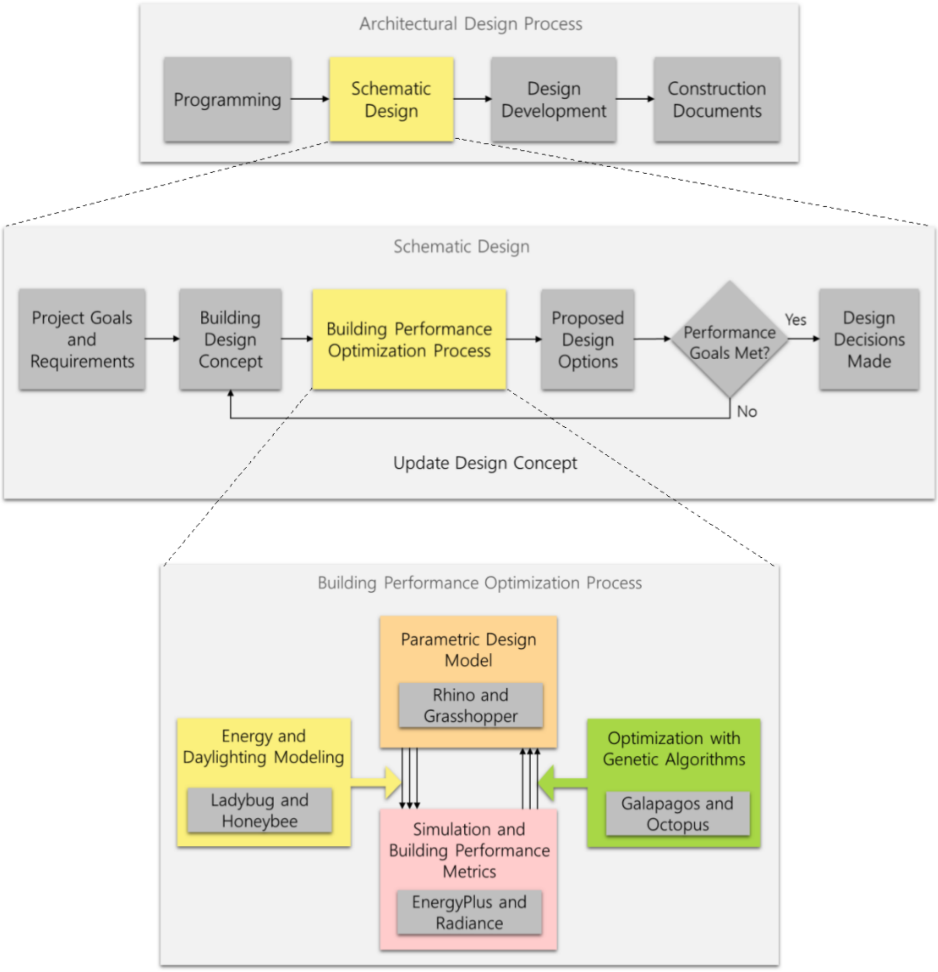

Figure 6: Building Performance Optimization in Architectural Design Process

Creating a parametric design model and determining the design parameters is the initial stage. The The optimization methods, which include daylighting, energy and radiation, comprise the third step. To completely explore building design possibilities under various aims and compare the performance difference, three optimization techniques have been divided. The analysis and evaluation of simulation results and optimal design comprise the fourth phase, which comes after the optimization processes is finished. The best designs are compared visually, and the settings of each optimised design are compared as well.

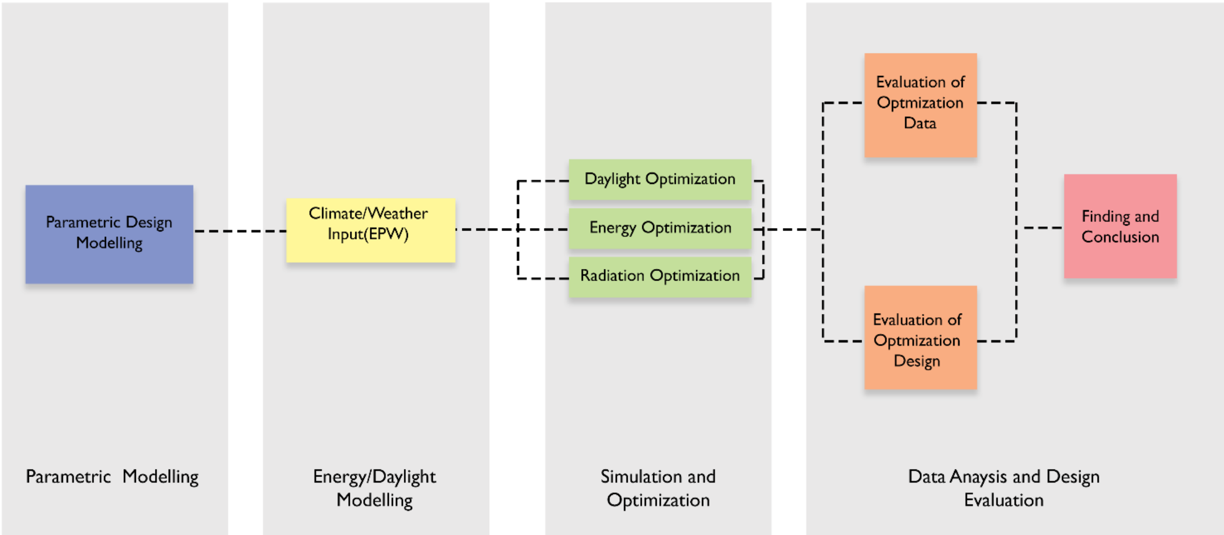

Figure 7: Research Diagram

Table 4 Building Parameters for Optimization Process

Name	Specification
Unit Mass Number	10
Column Grid (Bays)Number X	18
Column Grid (Bays)Number Y	12
Floor Number Minimum	10
Floor Number Maximum	20
Column Spacing X	8
Column Spacing Y	8
Exterior Façade Type	Simple Windows (For Daylight Analysis) Simple Fully Glazed Wall (For Energy Analysis) Simple Fully Glazed Wall (For Radiation Analysis)

EXPERIMENT AND RESULT

A collection of well-chosen criteria is essential to the goal of improving daylight consumption, radiation management, and energy efficiency inbuilding design. These criteria specify the essential features of the building under consideration in addition to being vital inputs for the optimization process. The building's performance with regard to radiation exposure, daylight availability, and energy consumption is greatly impacted by the values given to these parameters.

When taken as a whole, these variables provide a framework for an extensive investigation into building optimization. This allows researchers to assess a variety of design options and pinpoint arrangements that strike the ideal mix of radiation control, daylighting, and energy efficiency.

The capacity to modify parameters, such as those pertaining to weather data and building design, undoubtedly increases the optimization process's adaptability and usefulness. Researchers can adapt their investigations to other settings, climates, or project requirements by permitting dynamic adjustments in crucial factors.

Data Analysis - Daylight Optimization

The comprehensive daylighting optimization procedure is shown in Figure 8. Building geometry and parametric design variables are used in Grasshopper to start the process. The daylight and energy modelling functions are provided by Ladybug and Honeybee. The parametric building geometry is linked to the Radiance materials component during the daylighting modelling phase, allowing for the adjustment of material transparency, reflectance, and other properties. After that, the daylighting simulation component is connected to the building materials and configured with weather files, daylighting sensor locations, and other parameters. The simulation of daylighting is run in Radiance and a rad file is created. Following the simulation, Ladybug reads the daylight performance data, imports the simulation result file back into grasshopper, and creates a yearly lighting schedule.

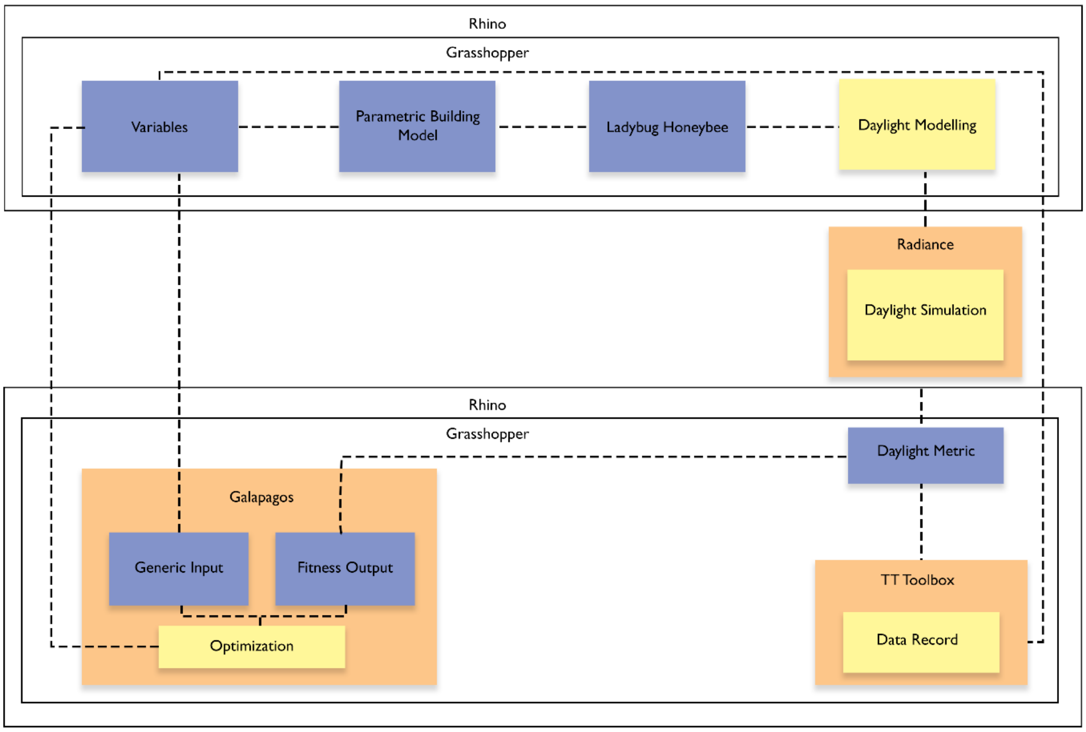

Figure 8: Daylighting Optimization Process and Tools

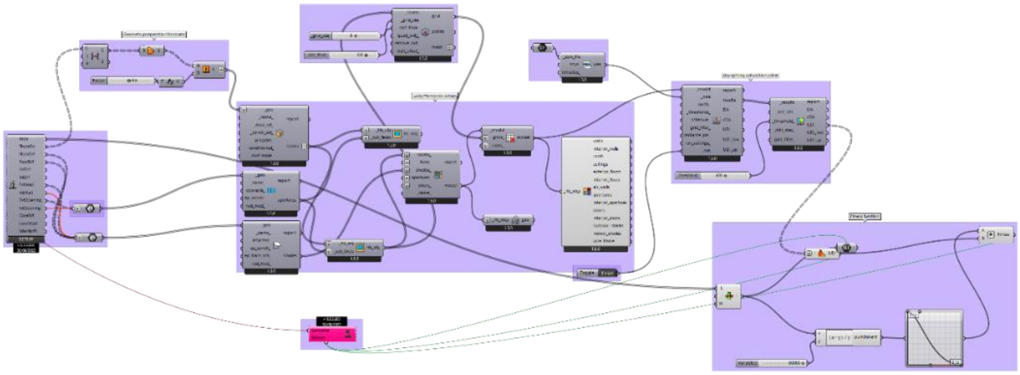

Figure 9: Grasshopper Script for Daylight Analysis

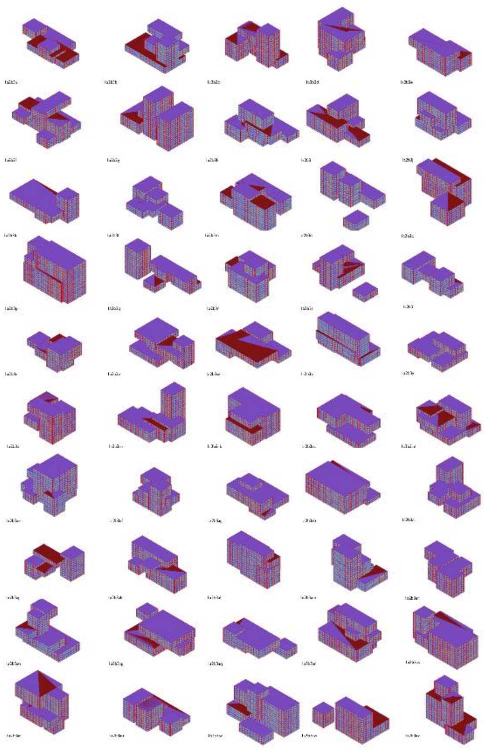

Figure 10: Result of Daylight Analysis

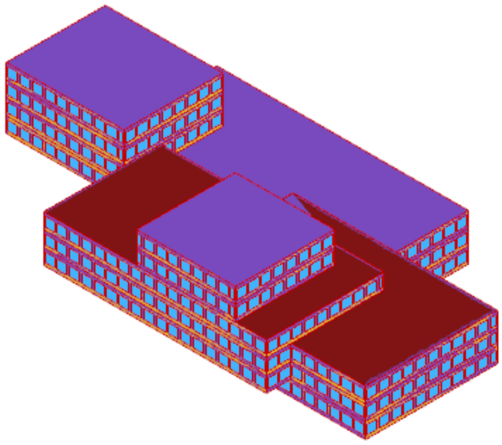

Figure 11 : Best Option as Per Daylight Analysis

Energy Optimization

The comprehensive energy optimization procedure is shown in Figure 12. The general process is equivalent to that of daylighting optimization only difference is for energy simulation climate studio plugin of Rhino is used for fast and accurate result. The optimization objective in this is the least amount of energy needed for the building. Thus, the whole energy load for lighting, heating, and cooling serves as the fitness input for optimization. TT Toolbox is used to export the design variables, energy metrics to a different Excel file.

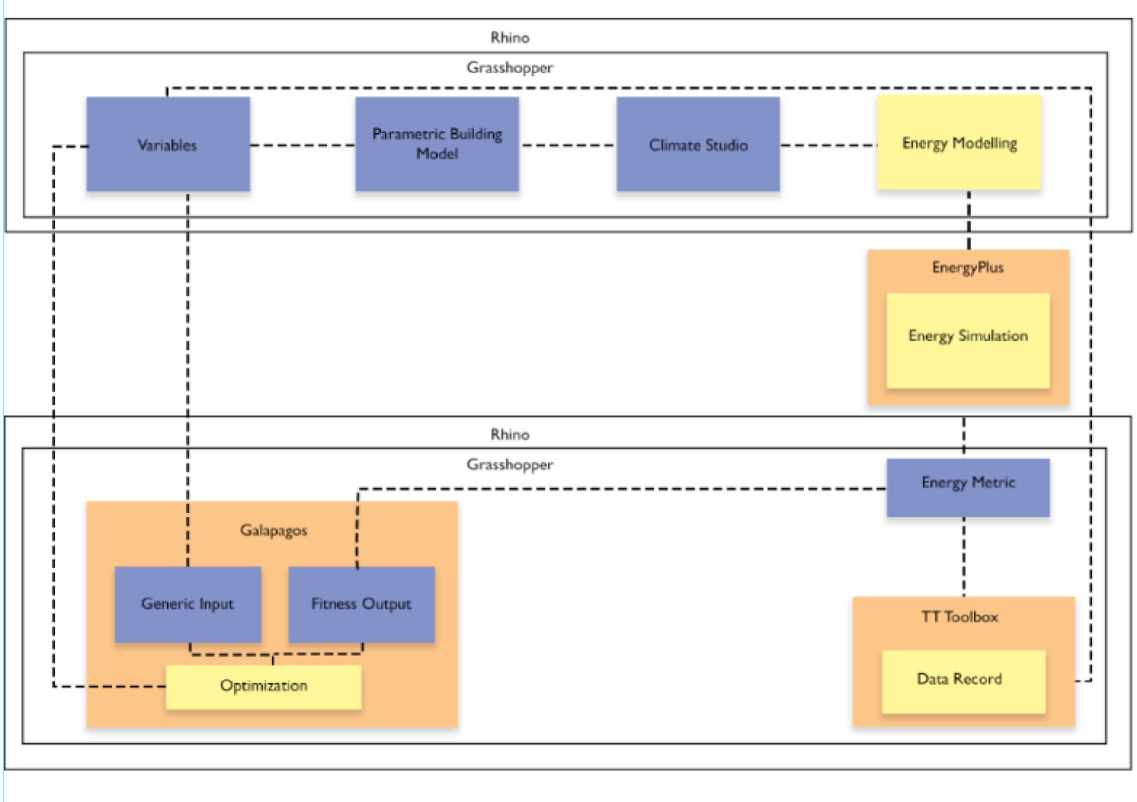

Figure 12 : Energy Optimization Process and Tools

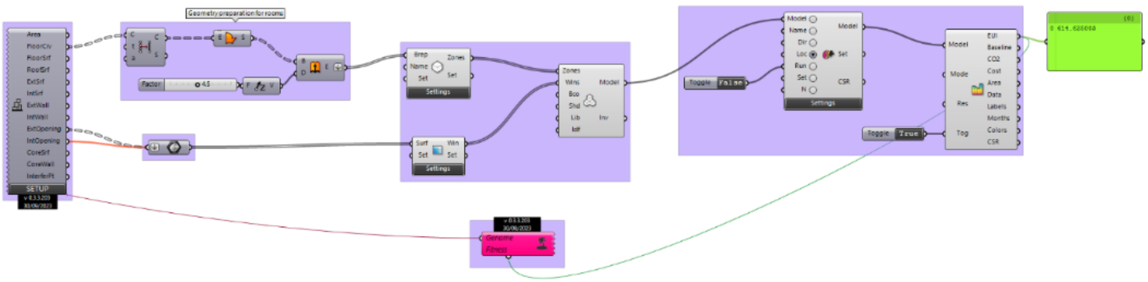

Figure 13 : Grasshopper Script for Energy Analysis

Radiation Optimization

The comprehensive radiation optimization procedure is shown in Figure 16. The process is the same as that of daylight optimization overall. There is only difference is optimization objective which is the maximum radiation that the building need. As a result, the total radiation in winter subtract from the radiation in summer serves as the optimization's fitness input. Using the TT toolkit, the design variables and radiation metrics are exported to a different Excel file.

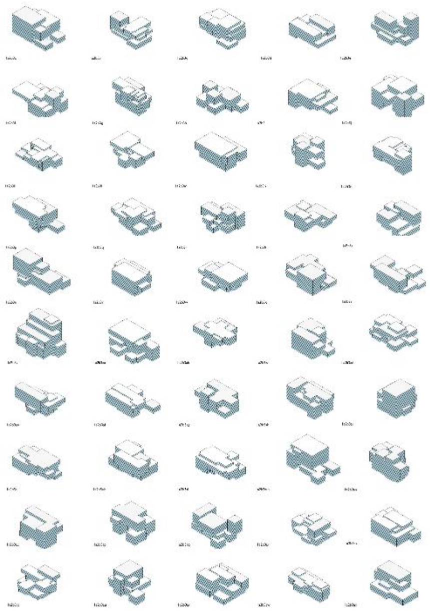

Figure 14: Result of Energy Analysis

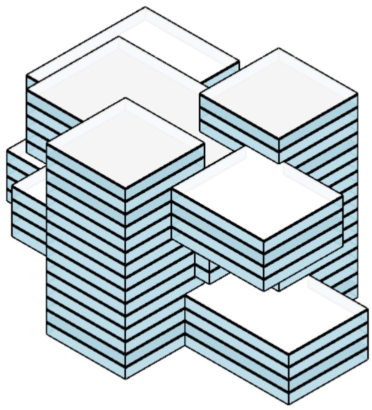

Figure 15 : Best Option as Per Energy Analysis

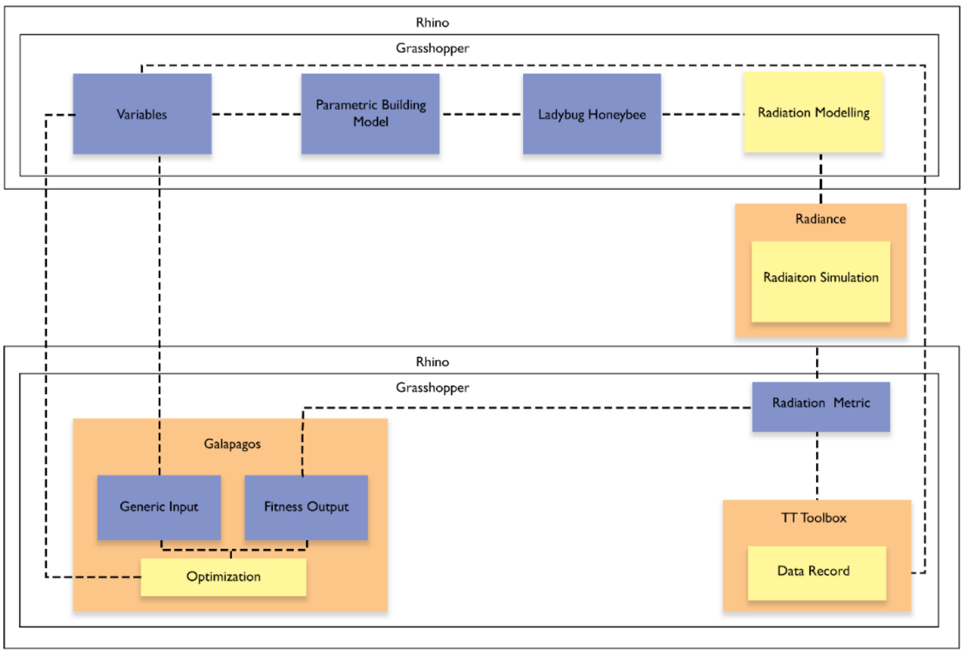

Figure 16 : Radiation Optimization Process and Tools

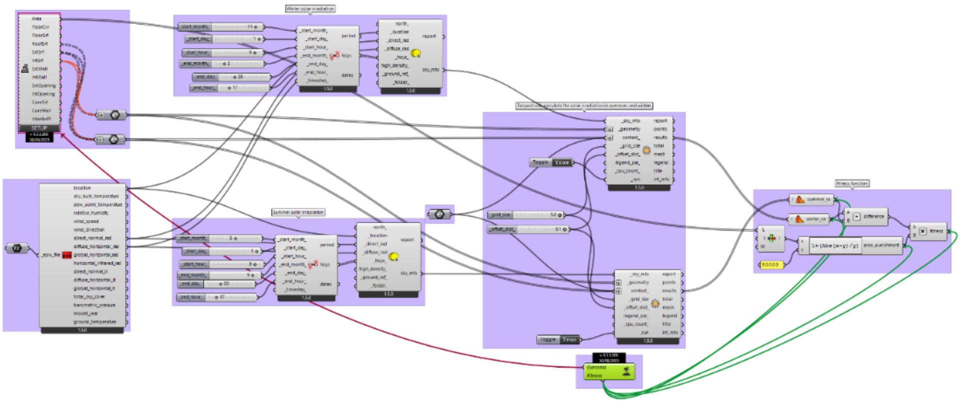

Figure 17: Grasshopper Script for Daylight Analysis

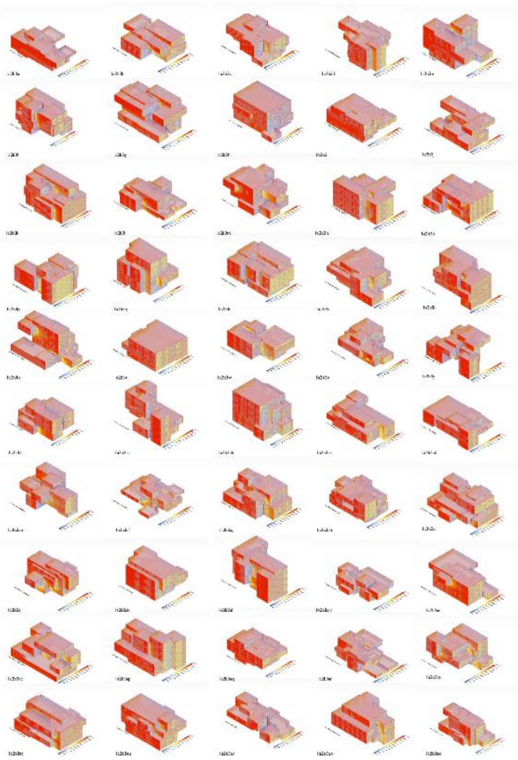

Figure 18 : Result of Radiation Analysis

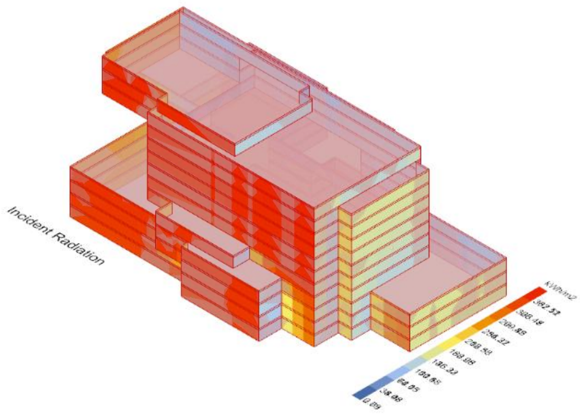

Figure 19: Best Option as per Radiation Analysis

Inferences

The optimization process involved generating 50 distinct design iterations for each analysis, using parametric design. This results in the identification of the best-performing form showing in Figure 11 (for daylight) Figure 15 (for Energy) and Figure 19 (for Radiation Analysis). This demonstrates the effectiveness of parametric design in achieving optimal design solutions.

Limitations

Due to the complexity of the optimization process, this method necessitates sophisticated computational design skills, energy modelling experience, and multi-program proficiency. Architects are still unable to smoothly integrate it into their design process. The generative algorithm, which is the optimization process used in this study. It is typical for any optimization procedure to produce distinct design solutions with varying levels of performance due to the random selection process. One of the greatest choices is the optimal design that is discovered after every optimization procedure. The global optimal design cannot be found mathematically.

The process makes extensive use of computer power. Despite the case study model's simple geometry, each scenario takes 24 to 48 hours to optimize, depending on the computer processor performance. Moreover, other programs are involved in this optimization process. An intricate design model has the potential to disrupt the optimization process by causing issues with data transfer across programmers. Therefore, additional technical support is needed to address more complicated design issues.

CONCLUSION

To sum up, the study "Parametric Sustainability: Optimizing Building Performance" offers insightful information about how parametric design principles might revolutionize the field of sustainable building. Building design may now be done in a dynamic and data-driven manner thanks to the integration of parametric modelling tools, which also present potential for performance metrics optimization. The study emphasizes how parametric sustainability improves occupant well-being, environmental responsibility, and energy efficiency. Through the use of parametric tools for thermal comfort evaluation, daylight analysis, and energy

simulation, architects and designers may design buildings that adapt dynamically to their environment, reducing energy use and improving indoor environmental quality.

A technique for optimizing building performance in the early stages of design was suggested by this study. All of these variables combined provide a foundation for a thorough investigation of building optimization, allowing scientists to assess a range of design options and pinpoint combinations that strike the ideal ratio between radiation control, daylighting, and energy efficiency.

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Digital Twins in Built Environments: Opportunities and Challenges

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Abstract— The Digital Twin (DT) concept was developed at the start of the twenty-first century, but it had not gained traction by the middle of the previous decade. The aim is to understand the digital twin concept and its application in design and urban planning. It is a concept that has been first introduced into the field of practical industrial products and has since expanded into a wide range of products and services. However, there is still no obvious purpose for these technologies or how they might be applied to address specific demands or assets in the building industry. The construction business has a tremendous economic and environmental impact, yet it lags far behind other industries in terms of digitalization. After a review of the research history in this field and its current use on the market, it proposes to analyze the aim, existing, and future state of digital twin construction within the industrial sector. The prior emphasis of this work was to apply the digital twin concept to construction, design, and building life cycle management, as well as to investigate the merits and drawbacks of such application. As a result, efforts should be directed toward technologies that can be used to translate into assets, such as intelligent management, and that will produce actual outcomes that can exist outside of the theoretical domain. It will allow work to be moved from the physical world to the digital world, resulting in considerable increases in productivity and effectiveness. The use of digital twins is critical to ensuring maximum performance, and they have proven successful in terms of cost savings and improved reliability for capital-intensive equipment such as jet engines, as well as in construction to improve building security and sustainability. Limitations of existing and emerging applications are also noted. It closes by emphasizing the value of DT applications in the building industry. This will allow work to be moved from the real world to the virtual world, significantly improving efficiency and effectiveness.

Keywords: Digital twin, Sustainability, Building Performance, Safety, Efficiency.

INTRODUCTION

In the last few years, this concept of digital twins as a way to understand, deliver, and manage building assets has been gaining momentum, particularly concerning asset management (FitzLeverton, 2022). The trend towards digitization, which is having a significant impact on business and society, is reflected in the digital twins. The Gemini Principles define a digital twin as an actual digital representation of assets, processes, and systems located in the real or virtual environment. Many people think of it as a simple digital replication of a real thing, a 'twin', but "what distinguishes a digital twin compared to any other digital model or replication is that it is connected to its physical twin," with the term 'connection' referring to a certain kind of collaboration and association between the physical and digital. This industry-agnostic idea is complex (Evans, Savian, Burns, & Cooper, 2018).

A digital twin is fundamentally made up of a digital template version of an organization, information related to that entity, a unique electronic representation of the thing based on the template, and the capacity to monitor the entity. The concept of a digital twin isn't fresh. It is commonly used in computer simulations in sectors such as manufacturing, aviation, and automobiles; however, its application to the physical world has not been a recent phenomenon. (Parmar, Leiponen, & Thomas, 2020).

Ultimately, digital twins give us the ability to better the environment in which we all live and work. Their structure and shapes have yet to be completely established but their potential benefits are already apparent. Construction environments are a comprehensive integrated word that describes human-made surroundings, including the design, approach of the leadership team, maintenance, and evaluation of both the functional and physical elements of structures and infrastructure. The most recent evaluation of the concept of digital twins in built environment studies involves the use of digital models of assets supplying simulations along with an instructive link to a true organization (i.e., a physical twin), which leads to opportunities for focused data selection in asset processes and management (Brilakis, Fischer, & Fellow, 2019).

Identifying and understanding such a wide range of what a twin might be has been extremely difficult, with differing opinions on the degree of maturity or characteristics that constitute a genuine twin. BIM, Building Lifecycle Management, and Product Life Cycle Management are comparable principles with some of the most important differences that form part of data collection and information management which is a key topic in these twines.

Digital twins, as an interface between the real and digital worlds, provide a variety of useful applications throughout the construction market and asset life cycles. The ability to collect, interpret, and exchange data is improving as sensors become smaller and cheaper, which makes the interface between worlds more important.

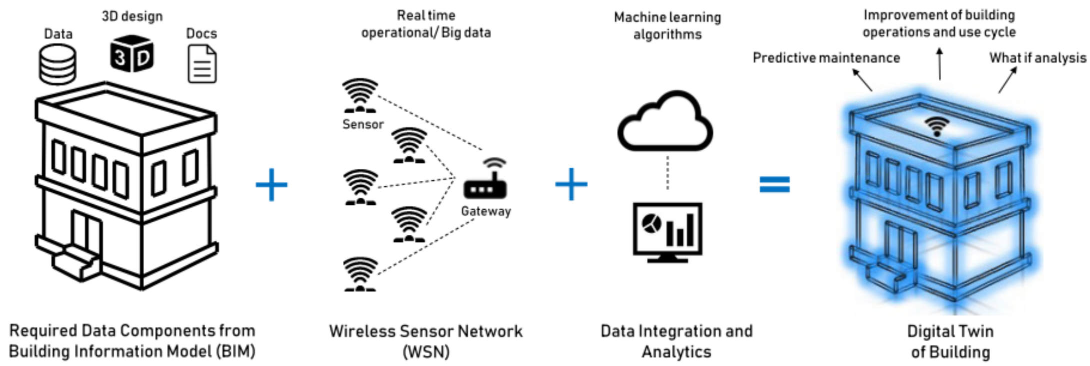

Figure 1. Essential components for creating a digital twin of a building and the distinction from BIM, source: (Brilakis, Fischer, & Fellow, 2019)

The construction industry has been highlighted as being hesitant to adopt technological improvements. The absence of urgency is a major hindrance to digital change. DT (Digital Transformation) is extremely disruptive, upsetting markets that are assumed to be tightly managed. Setting up DT entails significant, harmful changes to the construction method (horizontally, vertically, and longitudinally) by using information, computerization, communication, and connectivity technologies, the aim is to increase construction outputs and productivity while achieving project results and improving client satisfaction. (Adekunle, 2021).

Furthermore, by creating a system of sensors for the building exterior and gaining a digital twin, building developers and architects can improve the building's performance through alterations, renovations, and future construction design. Architects, for example, can use data on the directions of sunlight and wind acquired from the building's front to design a structure that takes advantage of these renewable assets to maximize illumination and airflow. This approach may enable them to develop a system that allows for energy savings in lighting, ventilation, and heating while providing the building's occupants with visible and comfortable heat conditions (Xu & Lu, 2018). Another potential application for digital twins is to produce an exact city digital twin. By combining non-proprietary name components of building digital twins, a more detailed and holistic model may be created, allowing planners in cities to attain unprecedented levels of accuracy in city planning, execution of projects, and operations.

Because of the growing demand for product lifecycle management, information on items must be easily available throughout their lives. At the same time, as supplier networks become more sophisticated (the "virtual enterprise"), there is a greater demand for firms to exchange product information. Increasing product modifications necessitates handling information at the product item level rather than the product category level, which substantially boosts the amount of product information (Främling, Ala-Risku, Kärkkäinen, & Holmström, 2007).

LITERATURE REVIEW

History of Digital Twins

No one could have predicted that when the oxygen tanks exploded at the beginning of the mission, it would turn into a battle for survival after the launch of Apollo 13 in April 1970. In 1998 the term 'digital twin' was coined to describe a computerized replica of Alan Alda's voice in "Alan Alda meets Alan Alda 2.0", although that concept had been around for many decades. Although since 2002 there has been a widespread recognition of twins in digital form. In 2002, when Challenge Advisory presented a technical demonstration for Michael Grieves at the University of Michigan, the concept of digital twins was acknowledged. While it is usually assumed to have originated in 2002, technology for digital twins has been a notion practiced since the 1960s (Miskinis, 2019). The NASA project required the construction of two spacecraft, with one on our planet as 'the twin' that replicated the space spacecraft carrying out the task (Boschert et al, 2018; Zhuang et al, 2018). According to Grieves and Vickers (2017), in tost mimic the physical framework, the DT must incorporate all of the real-world asset information acquired through a thorough investigation of the real world.

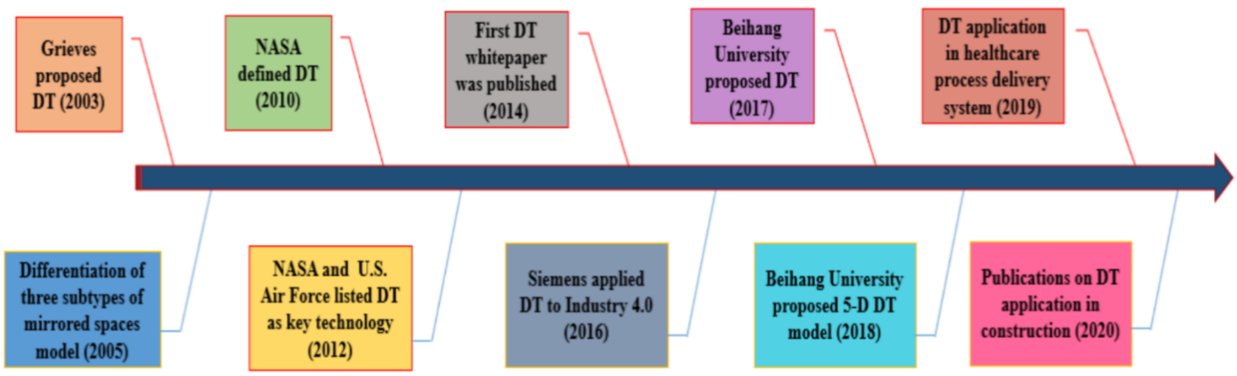

Figure 2. The milestone of DT development,
Source: (Obinna C. Madubuike, 2022)

Digital Twin Standards

Industrial data in TC 184 SC 4 are defined by the International Organization for Standardization. Currently, minimum specifications are being developed for the digital twin manufacturer network. For the Joint Technical Committee, which includes ISO and the International Electrotechnical Commission, the recently formed Joint Advisory Group on Emerging Technology and Innovation presented their Technology Trend Report, naming Digital Twin as one of four top emerging technologies out of fifteen. The findings prompted the formation of the Digital Twin Advisory Group (AG 11), which makes recommendations to JTC 1 (Ferko, 2023).

Digital Twin Types by Application

To make the most of the model of digital twins effectively, you must first understand the various forms. This will assist you in creating an ideal digital twin simulator for your business needs, as seen in Figure 3. As a result, virtual twins have different applications and hierarchies. There are four types of digital twins, organized in a hierarchy. The DTs could represent components, systems, products, or processes.

Figure 3: Digital Twin Classification by Application, Source: (Landyshev, 2023)

Benefits of Digital Twin?

Digital twins provide data on the planning and performance of an asset, for example, tenant behavior, use structures, occupancy levels, or traffic patterns. You can assess "what-if" scenarios, such as the consequences of design changes, weather disturbances, and security incidents, by using a digital twin. In just one environment, it collects enormous amounts of data.

How Does Digital Twin Work?

The Digital Twin is a combination of the building's systems, sensors, and utility meter data with smart mutative computer models. All the operational and behavioral knowledge required to imitate, predict, and advise real-world decisions is available in a true digital twin.

What Is A Digital Twin In Construction?

A Digital Twin, as the name implies, is a digital representation of a physical space. Through these 3D models, you may virtually engage with the real property during the initial planning and design stages. Working in the construction industry presents numerous problems. The most pressing concern is to maintain production. Digital twins will assist you keep it under control. Engagement with your stakeholders is faster and easier, which increases workflow efficiency.

How to Use Digital Twins in Construction?

Digital twins in construction are formed by merging multiple forms of data into a single platform, such as 3D models, information from sensors, and real-time performance data. This allows for the simulation and optimization of material choices, energy consumption, and maintenance schedules. Digital twins are also able to save downtime and increase safety by recognizing possible problems early on. To identify potential dangers and take precautionary steps, engineers can utilize a digital twin to mimic the impact of harsh weather on an infrastructure structure or bridge.

Advantages of Digital Twins

- **Collaboration And Communication -** Digital twins increase communication and collaboration in construction via offering an integrated environment for all parties involved to share knowledge, coordinate work, and make decisions.
- **Efficiency -** Digital twins can help construction companies become more efficient. These digital twins can significantly reduce the amount of time and money invested in project engineering by recreating the real-world environment in which construction teams work by integrating both digital and physical modeling of a project.
- **Construction Safety -** Identifying possible risks before they arise is critical in the construction sector, and the use of digital twins can assist improve safety.
- **Accuracy and Quality -** Architects and engineers can use Digital Twin to create structures virtually, complete with details about operations, materials, and maintenance schedules.
- **Cost- Savings -** Construction managers can use digital twins to simulate multiple design possibilities and evaluate their efficacy before construction begins, eliminating the need for costly revisions throughout the project.

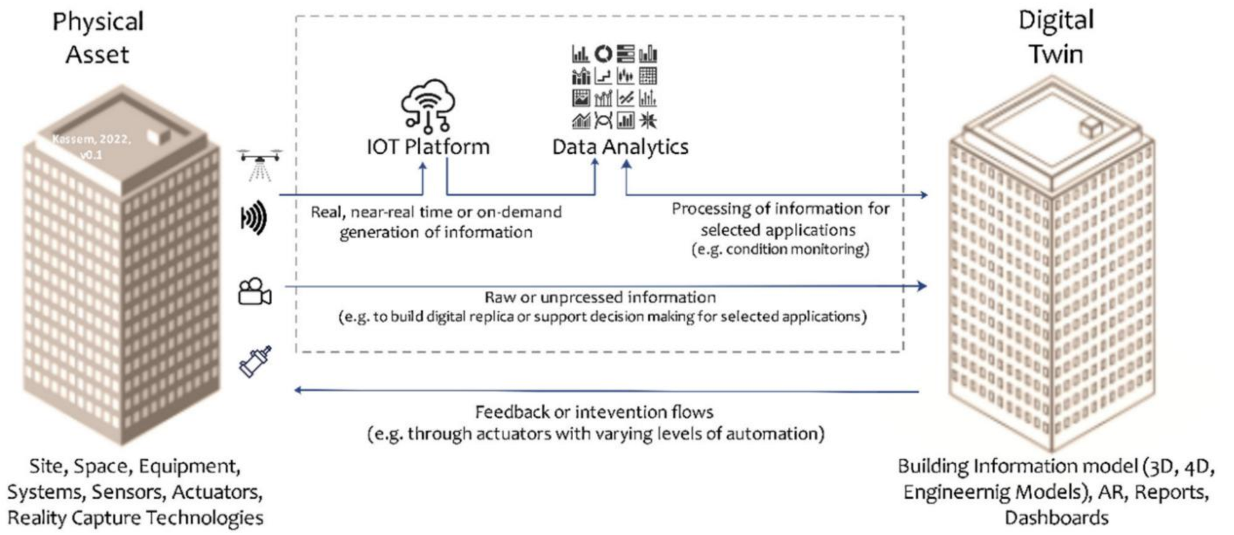

Figure 4: Essential components to create a digital twin of a building, Source: (Muhammad Shahzad, 2022)

Discussion

Heathrow Terminal 5, London, UK wasn't just about building another terminal; it was about creating a state-of-the-art hub that would cater to millions of passengers annually. It's a prime example of how digital twin tech can be a game-changer. With so many stakeholders, intricate designs, and tight deadlines, the digital twin gave the team a crystal-clear view of how things were unfolding. Leveraging digital twin technology, the project team had a dynamic blueprint in hand, allowing them to navigate complexities in real-time and ensuring every detail was executed to perfection.

The Edge in Amsterdam, Netherlands, is renowned as one of the worldwide most sustainable buildings. It achieved its excellent performance through the application of digital twin technology. The digital twin used multiple data sources, such as occupancy, energy use, and internal climate characteristics, to produce a precise representation of the structure. This enabled accurate oversight over heat, lighting, and air conditioning systems, reducing energy consumption and providing a comfortable atmosphere for occupants.

Suzhou Center in Suzhou, China, is an outstanding mixed-use complex that used technology known as digital twins to accelerate its construction. Digital twins were employed to model the functioning of the building's intricate structures, optimize energy use, and monitor the surrounding environment. This technology supported data-driven decision-making, allowing architects and engineers to design a sustainable and visually appealing building.

Crossrail London, an important building project in London, employed a digital twin system to track its development and identify potential flaws before they become big problems. The digital twin was utilized to model the constructing process and maximize resource utilization. The Shard London, a 95-story skyscraper in London, employs digital twin technology to improve energy efficiency and lower its carbon footprint. The digital twin was utilized to replicate the energy consumption of the structure and highlight potential areas for improvement.

In addition to the safety of players, Digital Twines are being used for sustainability and efficiency purposes in National Football League stadiums. For instance, Digital Twin technology has been used in the SoFI Stadium, one of the world's leading innovation sports facilities that hosted last year's Super Bowl. SoFi Stadium, US uses a digital twin to support the day-to-day maintenance of the building, which was designed by global technology company Willow. This virtual model is crucial for the management of a stadium with an area of 3.1 million square meters and 70,000 seats. In order to give administrators a holistic perspective on the stadium, its space and how best to use it, this Digital Twin contains information about facility equipment, existing conditions at the building as well as more. For instance, a part of the building with an increasing temperature has been identified by our Digital Twin. The Willows Analytics team quickly identified the device that was cooling this area of the stadium and has dealt with it without delay (Ranjan, 2023).

CONCLUSION

Digital twins are a powerful tool for architects and engineers, with the potential to improve building design, optimize energy efficiency, reduce costs, and increase safety. As technology advances, digital twins will become even more important in the field of architecture. The paper accomplished how the Digital twin technology offers substantial benefits to architecture and construction by revolutionizing how buildings are designed, constructed, and managed throughout their lifecycle. The integration of digital twins empowers stakeholders with real-time insights, improved decision-making, and enhanced collaboration, leading to more efficient and sustainable processes. In architecture, digital twins serve as virtual replicas, enabling architects to visualize and simulate designs, test different scenarios, and optimize building performance before construction begins. This reduces errors, streamlines workflows, and fosters innovation in design, resulting in structures that are not only visually appealing but also functionally efficient and environmentally friendly.

During the construction phase, digital twins facilitate better project management by providing accurate and updated information to contractors and workers. They enhance safety protocols, optimize resource allocation, and enable precise monitoring of progress, thereby reducing costs and mitigating risks associated with errors or delays. Post-construction, digital twins continue to add value by serving as a dynamic source of information for facility management. They enable predictive maintenance, monitor energy usage, and facilitate ongoing optimizations for improved building operations and occupant comfort. Additionally, these digital replicas facilitate renovations or upgrades by providing comprehensive insights into the existing structure. Ultimately, the integration of digital twins in architecture and construction represents a transformative shift, offering a holistic approach that enhances efficiency, sustainability, and functionality throughout the entire building lifecycle. As this technology continues to evolve, its impact on the industry will only grow, shaping a more innovative and responsive built environment.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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A Review of current research on Building Automation Systems for Commercial and Office Buildings

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Abstract— The courtyard, a fundamental element ingrained in the traditional residential architecture of India, has left an indelible mark across various regions, from the opulent Havelis of Gujarat to the rural houses of Bengal. This article explores the architectural and social dimensions of courtyards in western Indian Havelis, addressing a notable gap in existing literature. Notably, it scrutinizes the dimensions, particularly the height-to-width ratio, in comparison to current building guidelines. The methodology involves an in-depth investigation of four specific Havelis in Rajasthan, examining their historical timelines, unique features, and contemporary use. The analysis reveals diverse spatial hierarchies, gender dynamics, and multifaceted uses within Haveli courtyards. The selected Havelis - Mandawa, Nathmal Ji ki, Poddar, and Piramals - showcase distinct architectural philosophies, emphasizing the importance of front and back courtyards. Comparative assessments highlight variations in length-to-height and length-to-breadth ratios, providing insights for architects. Importantly, the absence of specific courtyard height guidelines in the National Building Code of 2016 is underscored, emphasizing the need for attention in contemporary architectural discourse. In conclusion, this research contributes to the discourse on courtyard design by unraveling the architectural significance and social dynamics within western Indian Havelis. The findings serve as a valuable resource for architects, urban planners, and preservationists, offering inspiration to create contemporary spaces rooted in the cultural and historical essence of traditional courtyards. Further exploration is encouraged, extending this research to investigate courtyards in vernacular architecture.

Keywords: Built environment; Courtyard; Cultural identity; Haveli; Vernacular architecture

INTRODUCTION

Approximately 40% of the total global energy consumption is attributed to buildings(Al-Muhtaseb et al., 2021). Various governments have implemented global energy reduction objectives in response to the prevailing climate emergency(Too et al., 2024). It is estimated that the building sector must emit a reduced quantity of carbon dioxide (CO2) annually, amounting to 9 Gross Tonnage, in order to make a significant contribution towards the mitigation of global warming, with the aim of limiting the increase in temperature to 1.5 ◦ C.(Wang et al., 2018) In an endeavor to mitigate the influence that structures impose on the natural surroundings, the introduction of building automation systems (BAS) was witnessed during the 1970s. These systems were implemented to regulate the functionality of heating, ventilation, and air conditioning (HVAC) as well as lighting systems, with the ultimate goal of ensuring a comfortable indoor environment within buildings(Bellido-Outeirino et al., 2012; Pellegrino et al., 2015). Traditional wired systems have served as a catalyst for technological advancement to such an extent that conventional controls can now be remotely accessed and accomplished through the utilization of a wireless sensor network (WSN) (Smart Building Systems for Architects, Owners, and Builders, n.d.). These intricate systems possess various strata, communication protocols, and compatibility. Building Automation Systems (BAS) can be defined as a technological solution that facilitates the manipulation of the electrical peripherals within a residential abode, transforming the static conglomeration of resources into a dynamic asset capable of providing an assistance to its inhabitants. Building Automation Systems (BAS) possess the capability to serve various objectives such as the facilitation of automation, the implementation of energy management strategies, the enhancement of security and safety measures, or the provision of assistance in the realm of daily living (Gomes et al., 2020).

Smart buildings, networks of Internet of Things (IoT), and BAS have been subject to extensive examination. On a larger scale, investigations into the broader utilization of Wireless Sensor Networks (WSNs) (Asad & Shoulaie, 2013) and their integration into the intelligent power grid have been carried out by references (Kumar & Hancke, 2014), in order to identify prospects for connecting buildings to the grid for enhanced management of their resource consumption. On a larger scale, subsequent evaluations have concentrated on systems for modeling buildings. It has been established that buildings seldom achieve their projected potential. A study conducted by Fabrizio and Monetti examined contemporary patterns in calibration methodology and techniques employed to identify uncertainties within the simulated environment in order to attain outcomes that are more in line with predictions(Fabrizio & Monetti, 2015). Macro and modelled building simulations offer projected performance metrics for the adoption of Building Automation Systems (BAS). The utilization of Internet of Things (IoT) devices has been discovered to provide an assistance in various specialized domains (Yared & Abdulrazak, 2016). Building infrastructures incorporate sensor networks to enhance the quality of life for senior citizens(Cahill et al., 2019). Numerous evaluations have demonstrated that enhanced accessibility and automated management of the building environment can augment the comfort of the elderly population, while concurrently reducing reliance on caregivers to execute basic tasks (Van Hoof et al., 2011). Previous studies of BAS have focused either on the level of systems communication, authentication protocols, access control and integration (Lobaccaro et al., 2016)Reviews of occupancy behavior and energy usage in the constructed surroundings have recognized three primary methodologies: (a) assessing individualized utilization by occupants (Pellegrino et al., 2015), (b) replicating occupant conduct, and (c) endeavoring to influence occupant conduct through the facilitation of interventions with participants, (Rafsanjani et al., 2015). The knowledge gap lies in the human engagement with BAS and its potential application in different domains. The suboptimal functioning of BAS can be attributed to human modifications of pre-programmed set points. Visual feedback loops offered by BAS can influence human-centricity and the comprehension of human practices (Ahmadi-Karvigh et al., 2017)

After an initial and thorough investigation, the authors discovered 63 articles that were published within the past decade from reputable sources such as Scopus, Web of Science, and Pro Quest. A distinct pattern became apparent upon closer examination. The focus of BAS research has primarily centered on the assessment of a singular linear component within the system, as opposed to considering BAS as a comprehensive closed-loop system. A comprehensive systems approach is defined as a collective endeavor involving the design process, ongoing stakeholder engagement, and the conscious utilization of learning and participatory methods through action, reflection, and dialogue. This approach emphasizes the importance of evaluating the overall achievement rather than solely focusing on easily quantifiable features or measures. Therefore, the purpose of this paper is to determine, analyze trends and patterns in Building Automation Systems (BAS). The underlying objectives of this paper are to (a) assess the influence of automation on user input, energy conservation, and demand response (DR), and (b) establish a research framework that can be applied on a large scale in both industry and academic research. The initial search for relevant publications has revealed a gap in research, indicating the necessity for a review of BAS research, encompassing design modeling, automation architecture, and occupant involvement. Moreover, it has been recognized that occupant participation and human input play a crucial role in BAS. The research question that guides the systematic literature review (SLR) process and subsequent meta-analysis is, "What is the current status of building automation in terms of user input, automation, energy conservation, and demand response?"(O'Grady et al., 2021)

LITERATURE REVIEW

Methods

The SLR is a stringent methodology that provides rigorous, repeatable and unbiased results (Siddaway et al., 2018). A review performed following predefined steps with results quantitatively analyzed is termed a meta-analysis (Cleophas & Zwinderman, 2017)To assess the findings within the publications selected by the SLR, we paired the SLR approach with a meta-analysis. The suggested reporting elements for systematic reviews and meta-analyses, or PRISMA, are compatible with this. In order to address the research question, we first defined three topics (controllers, benefits, and devices). Next, we came up with a list of pertinent keywords and synonyms that would help the search results. In order to make it systematic and repeatable for every user across all scientific databases, the third stage needed keywords to be inserted into a Boolean search string. Only certain terms, titles, and abstracts were searched. Words were separated by "OR" to ensure the search found the desired article material and returned both AND/OR results. The keywords were enclosed in quotation marks when they were two words long. The employed search engines (Scopus, Web of Science, and ProQuest) automatically look for the keyword's plural form. In order to restrict the articles to those that had a stronger match to the study topic, each Boolean search string was line split, with the 'AND' operator implying that one term from each line would be present: “Building Automation system” OR “Intelligent Buildings” OR “Internet of things” OR “Smart Building” OR “Automation with sensors and actuators” AND “Commercial Building Automation” OR “Automation in offices” AND "Cost saving" OR “Energy saving” OR "Power saving" OR "Energy demand in Commercial Buildings"

RESULT

Systemic Procedure

Multiple digital databases were searched to find pertinent articles. From important databases including ScienceDirect, Web of Science, and IEEE Xplore, review articles, conference proceedings, and peer-reviewed journal articles were found. Journal articles from a variety of disciplines, including social science, the arts, and humanities, are available in the Web of Science database. The IEEE library contains numerous periodical articles pertaining to engineering, computer science and energy science, and technical standards. ScienceDirect offers several publications from numerous disciplines, including papers in the physical, social, and life sciences, energy and engineering. These databases were selected because they provide easy accessibility to relevant and reputable publications.

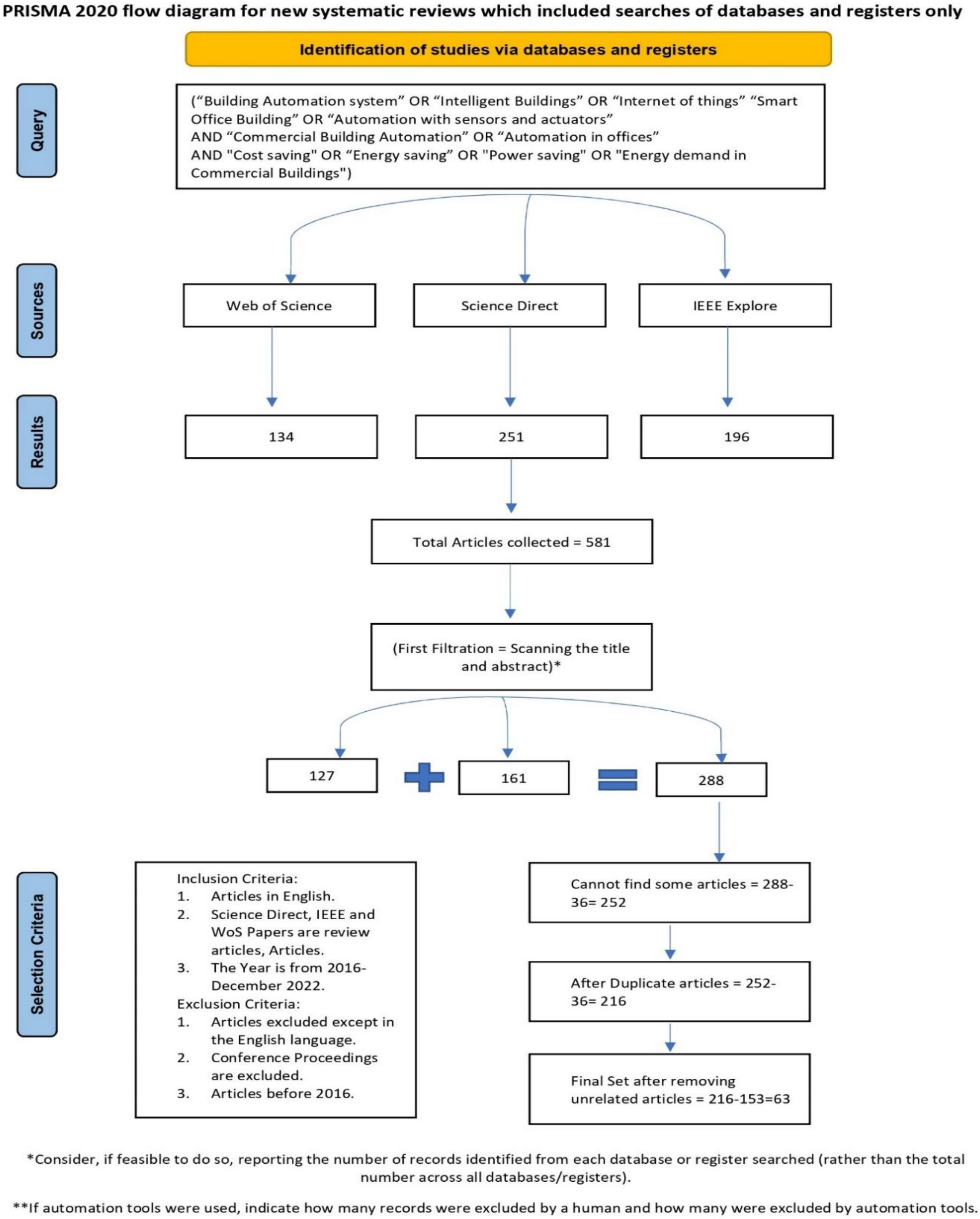

Figure 9 Prisma Chart for the Article Filtration and Selection

Selection Criteria

Web of Science, ScienceDirect, and IEEE Xplore's advanced search boxes were used to start the search. The search engine employed two types of Boolean operators: "AND" operators, which connected focus regions, and "OR" operators, which grouped terms with the same meaning. There were two sets of keywords (questions) employed (Fig. 1). Research publications, conference proceedings, and review articles were used as the criterion, filtration, and final set during the search procedure. This choice was thought to be the best one to ensure that the most recent studies in the field that the researchers were interested in evaluating were included. (Kim et al., 2022)

Among the 63 articles altogether which made up the final selection, the search was restricted to the research works published during the past 10 years; the majority of these have been published after 2015. These statistics show that building automation research is becoming increasingly popular. A large quantity of literature on intelligent buildings and building automation has been produced over the previous two decades. But most of them were addressed to the residential sector. Hence, in the case of commercial buildings, there is a dearth of a comprehensive assessment of previous research efforts and successes. Our study indicates a new dimension and possible area of research on the topic of Building Automation and Energy Efficiency in Commercial and Office Buildings, which is backed by the literature. Lastly, we tried to touch on another aspect of its applicability in countries like India.

Search coding

The coding within the selected databases is as follows: (“Building Automation system” OR “Intelligent Buildings” OR “Smart Building”) AND (“Internet of things” OR “Smart Automation” OR “energy efficient” OR “Automation with sensors and actuators”). The focus was only on the search for conference proceedings, reviews, and journal articles. The systematic review operated under the title, abstract, and keywords into relevant and selected databases. The articles were filtered into three rounds as described and specified in the following sentences (Siddaway et al., 2018). The first round of searching in the databases of Web of Science, ScienceDirect, and IEEE Xplore cumulatively generated search results of 6625 articles. In the second round, to ensure that relevant articles that suit the purpose of this review were included, the output from the first round was evaluated and examined by using the scanning title, abstract, keyword, goals of the study, and conclusions. The number of papers was 288. In the third round, the publications were fully reviewed and analyzed; 36 articles cannot be found in the Web of Science database, 153 are not related articles, and 36 documents were duplicates. Only 63 remaining articles were consistent with the inclusion criteria of the PRISMA protocol. Several notes and comments were recorded while information from the publications was extracted. Each article was analyzed separately by using different items with many attributes recorded into Microsoft Word tables.

Inclusion and exclusion criteria

In Fig. 1, there is a list of all the articles, including those that satisfied the requirements for inclusion. English-language publications, publication years between 2014 and 2022, review articles, research articles, and mini-reviews for ScienceDirect papers, journals, magazines, and early-access articles for IEEE Xplore papers, and articles and reviews for Web of Science papers are the inclusion criteria. Without any limitations, these categories were drawn from pre-survey literature. The articles were disqualified in the first round if they did not meet the eligibility requirements. The final set of articles chosen for this review was made simpler by removing duplicate articles from databases and missing articles in the second round. The exclusion criteria were as follows: non-English language papers published before 2014 and books, bibliographies, theatre reviews, reports, and others. Fig. 1 Presents the search queries, search results, and the inclusion and exclusion criteria.

Table 1. Final Filtration of Articles

Final Filtration of Articles from final set of 288 articles	
Number of articles which was unable to access =36	Remaining Articles = 288-36=252
Number of articles found duplicate = 36	Remaining Articles = 252-36=216
Final set of unrelated articles to focused area = 153	Remaining Articles = 216-153=63

Research Analysis

The search was restricted to articles published during the previous ten years; 48 of the 63 articles that made up the final selection were released in or after 2016, this figure demonstrates the popularity of the BAS. (Figure 2)

These figures demonstrate how building automation is becoming more and more popular over time. The majority of the articles (17) focused on the fundamentals and system architecture of the BAS theory; the trend that received the most attention was the articles (12) that dealt with how easy it was to work with technology. The second-most researched trend discovered is the energy perspective in the buildings (11) and the ease of operation (11). According to the report, human comfort via BAS (8) is the third most discussed factor. The assessment revealed that the least researched domains were the cost (2) and the environment aspect (4). It should be mentioned, though, that the majority of the research was qualitative in nature and largely consisted of reviews and criticism on the technology that is now in use. The 16 articles contain the experimental and algorithm work, which may reflect the difficulty in obtaining full-size case studies for testing, which could have an impact on the real implementation costs. Lastly, of the chosen articles, only six noted a decrease in building emissions. This makes buildings' emissions the least discussed category. (Figure 3)

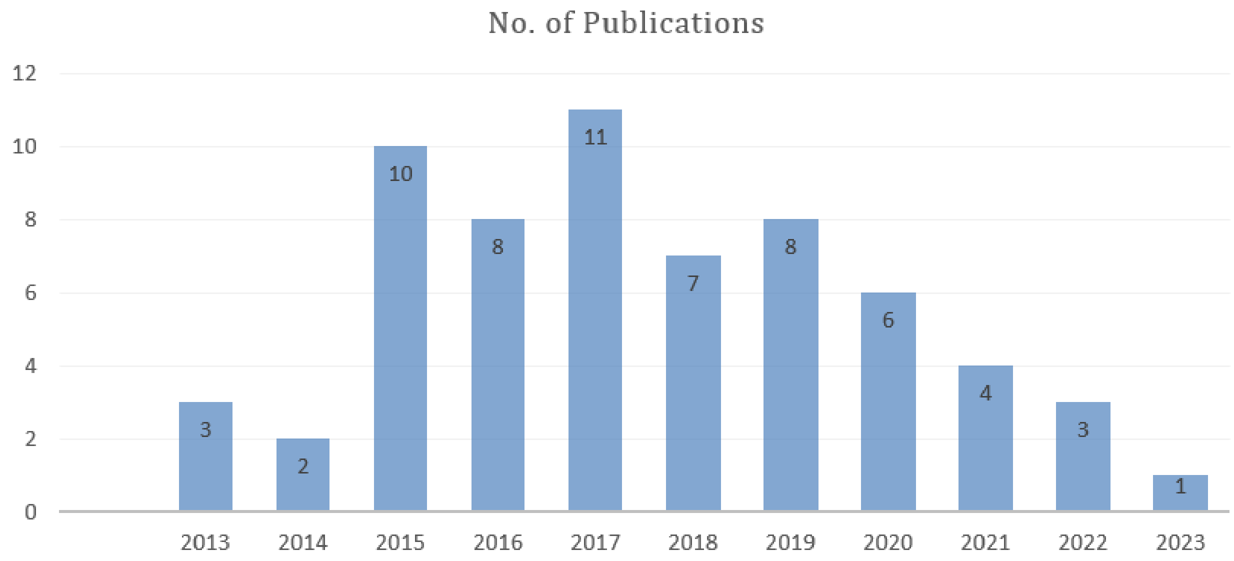

Figure 10 Distribution of number of articles published per year during the past 10 years

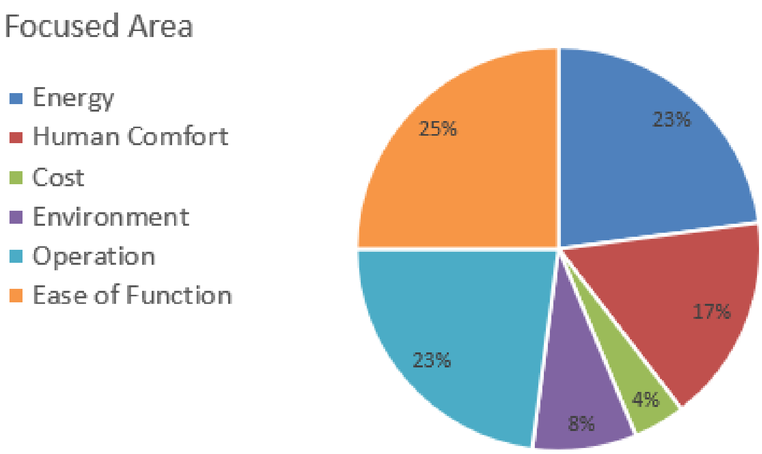

Figure 3 Focus area of the Articles

Furthermore, research was strongly biased towards three regions: Europe with 53% (41 publications), Asia and Oceania with 31% (24 papers), and the United States and Canada with 16% (12 articles). The remaining case study locations were outliers in South America, Africa, and Oceania. Each study's focus was location-specific because the sorts of buildings where BAS are used and whether heating or cooling is necessarily having a major impact on how much energy is used in the built environment. Given that the created structure's functionality is significantly impacted by daylight hours, light penetration angles, and solar intensity, it is obvious that modeling should take geographic location into account. (Figure 3)

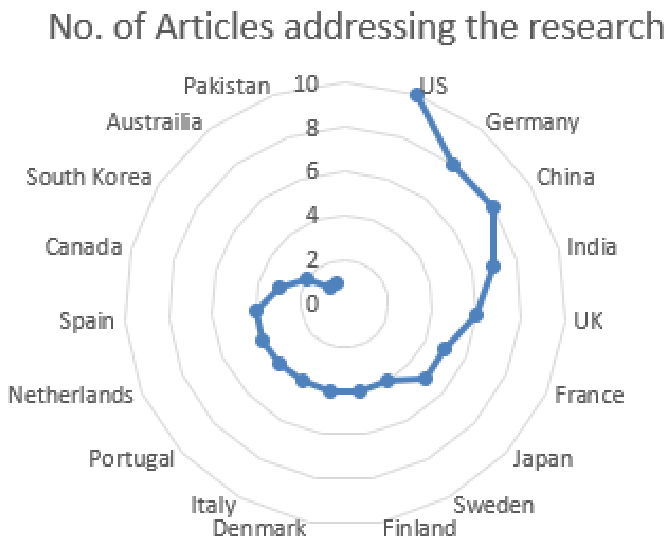

Figure 11 Research Article Distribution as per the country

Software used in building automation research

The majority of scholarly investigations into how automation affects the built environment have relied on computer modeling. There are several benefits of using simulation modeling instead of field tests, including the following: 1. It enables performance evaluation in situations when field experiments are impractical (Demeure et al., 2015), 2. Allows energy savings to be estimated before implementation (Koseoglu & Nurtan-Gunes, 2018), 3. Cuts down on time and costs (Li et al., 2016) 4. enables tasks to be completed repeatedly in order to evaluate the impact of a parameter(Engelsgaard et al., 2020) 5. Approves control methods like weather((Babu et al., 2019)) 6. doesn't bother building inhabitants in any way(Agarwal et al., 2010). 7. Provides the ease in understanding the data(Yang et al., 2012). With a multitude of software suppliers focusing on different aspects of the construction system, modelling software is becoming more sophisticated. The modelling program that has been shown to be utilized in scholarly studies is displayed in Figure 5. Designers can obtain qualitative data using modelling software without having to physically install or modify a device within a structure. This is demonstrated by the fact that out of 6 articles that use EnergyPlus, only 6 contain modelling findings that are supported by case studies. Modelling software is very essential for the academic research, as it may be found to be costly if when we directly proceed for the direct implementation of any technology, also it may be out of reach to many of the researchers as well (Karadayi, 2017).

The fundamental theoretical set of predictions needed to compute savings in the virtual built environment is provided by modelling software; it's crucial to remember that they only hold true in ideal circumstances. Research has shown that a building's occupancy and how people interact with it influence the expected energy-saving outcomes, and that in order to get the best results, a building must be fine-tuned even after it has been put into commission. Since latent energy consumption and parasitic loads vary depending on the building and project complexity, this emphasizes the necessity for more field case studies to examine differences between models and actual data (Floris et al., 2021).

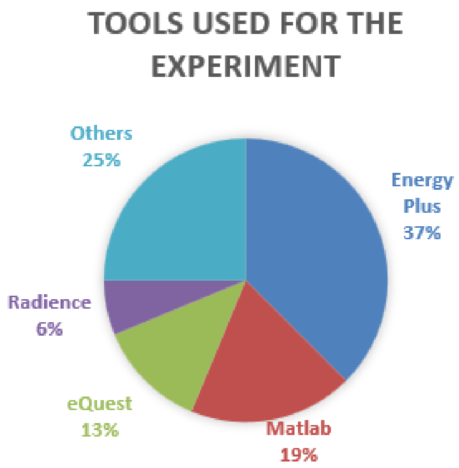

Figure 5 Software used for the Experiment

Nature of research

Variety of queries were answered during the literature study. The outcome in the larger umbrella of BAS has covered various sub-topics, some article(s) addressed the global perspective and some covered the Indian trends (Fig.6 and 7). One research focuses on building energy management systems. It explores the impact of occupants' interactive behavior on building energy performance. The research involves the use of the DNAS ontology to describe the impact. In the process, building performance modeling is used for advanced control of building energy systems (Choi et al., 2015). One research by Hemanth ___ focuses on energy efficiency and resource management in buildings Explores advanced experience of energy efficiency in residential fields aimed to make energy efficiency more widespread and enhance it further Considers economic, social and environmental factors in energy management. It also included requirements for new and existing buildings in Germany's energy efficiency policy. Wong & Li investigated and develop the intelligence indicators for an integrated building management system (IBMS) which was conducted within the context of intelligent buildings in Hong Kong Focus on commercial intelligent buildings, specifically for office buildings.

They also explored features of biologically motivated behavior, cognitive-based behavior, and characteristics of neuroscience (Wong & Li, 2009). In 2016, A research of Yared & Abdulrazak, focuses on the growth and potential of home automation market. It explores the benefits of automated home assistance for the elderly and people with disabilities. They predicted that increase in adoption rates and installation of smart home devices(Yared & Abdulrazak, 2016). Lastly, they discussed the concept of Internet of Things (IoT) and its role in home automation. One research uses the Delphi method to identify issues concerning IoT adoption. The study also aimed to develop an IoT adoption measure. It Provided qualitative insights on issues significant in the Indian context. Outcomes of the study are extendable to similar environments. The research is focused on energy and comfort management in intelligent buildings (Thangamani et al., 2022). Yahyazadeh et al.'s research focuses on energy performance in buildings. It provides policy analysis, advice, and implementation support, the research aims to support evidence-based policy making. Research conducted European Commission. Joint Research Centre., 2019 (the Buildings Performance Institute Europe) provides evidence-based scientific support to European policymaking process.(Yahyazadeh, 2023)

The research focuses on implementing demand response in commercial buildings. The research aims to reduce building's peak load and improve grid efficiency. The research integrates control of cooling, lighting, and plug loads in commercial buildings. The research evaluates total building performance and interdependencies between different systems. The research discusses the potential of buildings to shift or shed electrical demand during a DR event. One research conducted by Singh et al., 2019 focuses on Energy Information Systems (EIS). The research aims to provide a simplified "EIS-in-a-box" product. The research addresses the diversity and complexity of office spaces and electrical circuitry. Qualitative research conducted on a smart grid pilot project in Panipat city, Haryana, India. Focus on understanding the motives and modalities of the truth machine. Martirano et al., 2014's research aims to optimize energy performance and comfort in office spaces. A Fuzzy logic is used as a robust algorithm for the control system. The research includes simulations and sensitivity analysis of different scenarios. The research considers the use of solar energy and dynamic elements in building automation systems.

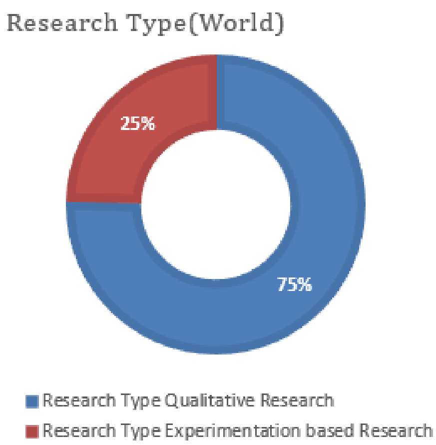

Figure 6 Research Articles in World Context

Another research focuses on developing an automated building energy modeling tool (Kamel & Memari, 2018). The tool, Automated Building Energy Modeling Tool (ABEMAT), uses Building Information Modeling (BIM) and modified source code of energy simulation tools. ABEMAT provides fine-grained outputs for heat transfer through building envelope components. The tool is compared to EnergyPlus for validation of its functionality. ABEMAT offers a faster, easier, and less error-prone process compared to traditional methods. The research includes a methodology for data validation using a model of a one-story building. Another research focuses on developing a cost-effective building retrofit decision-making model. Research is conducted in China's temperate and mixed climate zones. The model considers local climatic conditions, building features, and retrofit costs. A net present value (NPV) is used to analyze the feasibility of retrofit solutions. The optimal retrofit solutions are identified for high-rise residential buildings in different climate zones. The model helps in devising suitable sustainable retrofit measures for existing buildings. The research aimed to achieve energy reduction targets set by governments. The study provides insights into the most influential factors and uncertainties related to retrofit measures (Andargie et al., 2019)(He et al., 2021)

In the world context, the number of qualitative research articles studied are 49 and the experimentational research articles are 16, which is around 75 and 25% respectively. Surprisingly, the a slightly different trend was observed in the nature of the articles of Indian context, here in Indian context, out of 7 articles, 3 are addressing qualitative aspects of the BMS and 4 are covering the experimentational research (which is 43 and 57% respectively). This indicates that in the Indian context the more qualitative, review and commentary-based research is a need. However, if compared with the world, Indian research should be focusing more in producing a large quantity of qualitative research.

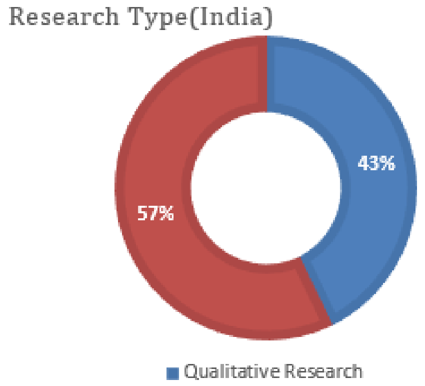

Figure 7 Nature of Research Articles in Indian Context

Discussions

Since people spend more than most of their lives in buildings, tenant behavior is one of the main factors influencing how much energy a building uses. The terms "occupancy" and "occupant behavior" describe people's presence within buildings and their active engagement with different BAS, including window blinds, plug loads, lighting, heating, and cooling. (Dong et al., 2018).

Most of the literature articles addressed the related use of technology, followed by a closer look at the technology-related aspects of safety and security, and privacy and ethics.(Van Hoof et al., 2011) Then some section followed them by having a discussion on engineering solutions that are implemented to assist users on various levels. Then, there is a discussion of the costs and benefits of intelligence technologies for the implementation in the provision of health care. (Jog et al., 2015)

Challenges

Research shows BMS research has various challenges too, some of them are listed here:

i. Its complex, dynamic and require a partially observable environment for the function.

ii. Sometimes it produces heterogeneous data sources and unreliable data.

iii. In many regions it was observed that it was conflicting needs and changing user habits.

iv. It requires every activity modeling and their recognition.

v. It lacks somewhere in understanding the context representation and contextual reasoning

vi. It is often found that there is lack of availability of datasets (Mekuria et al., 2021)The technical interoperability concerns with the translation of messages and codes from one protocol to another, which is usually performed by the so-called network gateways (Domingues et al., 2016).

vii. The technology needs to be continually developed to meet the challenge of domestication (Lobaccaro et al., 2016)

viii. As a result, no matter how successful a management system turns out to be, it will only last as long as the data display is adaptable and can change over time (Ahmadi-Karvigh et al., 2017)Ultimately, in order to create a functional building automation system that can communicate with users, it is necessary to consider still another important obstacle, which is consumers' understanding of smart technology (Bellido-Outeirino et al., 2012). Not only must smart appliances be installed and set appropriately, but users' understanding of energy management and other smart device features must also be continuously raised (Engelsgaard et al., 2020). Another research tried to put a light on the BMS research challenges by identifying various challenges related to sensing in smart cities, both of a technical and social nature. Some of these challenges are:

i. Addressing and coordination issues between sensor nodes.

ii. Security: Enabling technologies for sensing applications pose challenges for smart cities. These networks will be vulnerable to cyber-terrorism and vandalism.

iii. Centralized control: Study suggested a shift towards centralized control, with all services aggregated and handled by a single system. Governments have unlimited control, which may lead to unlawful tracking and privacy invasions. This relates to the trust and privacy concerns already addressed.

iv. How much will it cost to update present cities to smart cities? Updating smart city systems, which rely largely on communication and infrastructure, may be costly. (Kumar & Hancke, 2014).

S. No.	Level	Contribution	No. of Articles
1	Process and Communication	Programmable logic controllers utilize digital and analogue inputs/outputs from sensors and actuators at the component level to function as a process control system. Computers are utilized in intricate systems to record, show, and communicate the status of operational systems. Enhancements made to this procedure have minimized the energy usage in buildings, as BAS now provides more decision-making options through sophisticated fuzzy logic controls.	18
2	Device	The device level consists of counters and timers which save, show, and manage the order of events related to a controlled device such as blinds, windows, and lights. Controlling blinds to either block or allow light into a room has been proven to have the greatest impact on HVAC and lighting energy use.	11
3	Component	Sensors, switches, and relays have the potential to help conserve energy. They work by identifying predetermined conditions and communicating with BAS devices, establishing a loop for providing feedback.	21
4	Macro systems	The macro system involves using modelling simulations and software to forecast the sequence of events and measures to decrease consumption. Studies at this stage have helped enhance comprehension of building performance. Designers can use modelling programs to predict sun angle, glare, and light distribution during the design phase, which improves energy savings from installed BAS. Utilizing modelling software eliminates the necessity of creating a case study exclusively for implementing researched systems or technology.	13

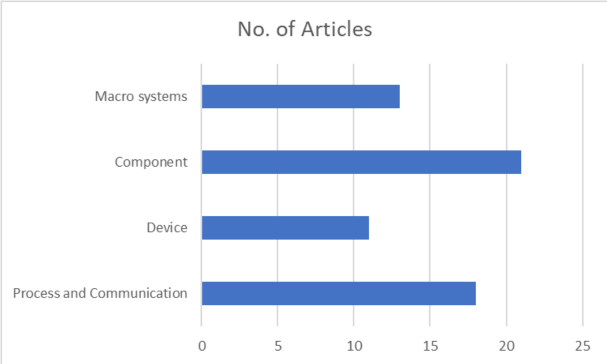

Figure 8 Research conducted based on IBMS sub-domains

The data presented indicates a pressing need for research focused on the device level of building management systems in contemporary times, while investigations into Integrated Building Management System (IBMS) components and processes related to communication are currently being extensively pursued. This suggests that while there is a wealth of knowledge being generated about the overarching frameworks and communication protocols that govern IBMS, there remains a significant gap in understanding the specific devices that operate within these systems. These devices, which include sensors, actuators, and controllers, play a crucial role in the overall functionality and efficiency of building management systems. Therefore, it is imperative that researchers direct their attention to the device level to enhance the performance, interoperability, and reliability of these systems in modern buildings.

CONCLUSIONS

The studies and research described above were undertaken by different groups at different periods, using varied approaches and assumptions, focusing different domain of research in the field of Building Management Systems (BMS). Several independent studies have found that integrating building technology systems improves efficiency, functionality, and operational performance while lowering costs. Some suggested a suitable algorithm for the application of BMS in various sectors. There were series of articles we witnessed which addressed the policy framework and policy analysis in the light of BMS.

Mostly, those articles were rather focusing in the home automation or a part of residential automation systems, which underlines one gap and urge to undertake more quality research towards office and commercial sector. Out of all the articles roughly 8% articles of the final selection were talking about research on Indian cases, which also reveal a strong potential of research in the BMS/BAS in India. A bunch of researches also talked about smart grid systems and its importance in the energy saving dynamics.

Experimentation and analytical type research were focusing more on the cases of development of intelligence analytic models for the IBMS in the intelligent building. And some of them were successfully able to elicitation and examination of 'suitable' intelligence indicators for IBMS. Simulation based researches shed a light on improved understanding of building's peak demand reduction potential through data. Such researches also catered ABEMAT research, which automates the process of building energy modeling and assessment. Which concluded that with the help of simulation and prediction modelling, a handsome savings can be achieved by designing computerized logic (PLC-SCADA) based service. (Varma et al., 2017)

This paper tried to touch large quantity of literature on intelligent buildings and on building automation has been produced of various sub-domains during the previous two decades. And it was found that most of them were addressed to the residential sector. Hence, in the case of commercial and other typology of buildings there is a vast scope of research. This study expands on existing information on BAS by identifying research gaps related to energy savings, DR, and human interaction and acceptability. Certain limitations of this review need to be noted. The first comes from using stringent search strings for a full systematic evaluation. The review focused on the last 10 years of published research, with limited literature from beyond the data gathering period.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Exploring Bio-Inspired Facade for a Sustainable Future

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Abstract- Façade designing has been evolving to complex parameters, aiming to increase the sustainable requirements of the building. Responding to the increased concern about the role of building sector in energy consumption and its disastrous environmental impact, a shift in thought process has been going in the field of architecture and construction industry. Bio-inspired designs can be one of the possible sustainable solutions to this problem. Various sophisticated mechanisms of nature provide innovative solutions to mankind over thousands of years. Natural processes incorporate sustainability principles to a larger extent than manmade systems. This research paper is a review of secondary data containing existing published and unpublished research papers and report addressing the ideas of bio-inspiration and its key aspects i.e. biomimetics and biophilic. The comparative analysis of case studies of Media- TIC building, Barcelona (2009), BIQ (Bio-Intelligent Quotient) apartment building, Germany (2013) and Shibori Office, Gandhinagar, Gujarat (2021) built on the principles of bio-inspiration helps in overall understanding of the concept. This study contributes to a better understanding of the functional correlation between the skin of organisms and the building facades. The comparison of façade to organism skin and body shells provides the list of roles that traditional façade typology only partially fulfils and enables for innovative designs. The aim is to study the recent technological advancement and opportunities in sustainable façade designing. The scope is to extensively validate bio-inspired strategies and active material research is required to obtain findings in order to efficiently transfer biological technique into technological solutions. This research concludes that bio-inspiration not only shows innovative design principles that are derived from nature but also signifies a promising shift towards sustainable architecture solutions for the future.

Keywords: Bio-inspiration; Biomimicry; Biophilic; Façade Technology; Sustainable Design

INTRODUCTION

According to UN Habitat report (2022), cities use more than 75% of the world's primary energy and contribute between 50 and 60 percent of greenhouse gas emissions worldwide. Our buildings are major consumer of energy. Moreover, limited resources necessitate attention to harmful consequences of building sector and preserving natural resources, making sustainability crucial for energy efficiency and combating climate change (Faragalla & Asadi, 2022). Façade system is a positive approach to this problem that reacts to changing outdoor conditions and harness environmental benefits into the buildings (Kim & Torres, 2015). Moreover, in today's world, demand for energy efficiency and highly controlled interior environment put a huge responsibility on the architects and the engineers to design facade more sustainably. Nature is an efficient tool. Various cycles and systems in ecosystem are interconnected with each other in a balanced way and help us to provide bio-inspired solutions. Traditionally bio-inspiration design thinking was limited to imitate the natural forms and shapes. But in recent times, designers study the operational and functional characteristics of the organisms with their natural adaptation methods to develop innovative, flexible, adaptive design solutions through façade architecture. Hence, the biological comparison is incorporated into today's façade architecture and providing inventive solutions for energy consumption in the buildings (Tokuç & Özkaban, 2018). The façade system that uses bio-inspired solutions control interior spaces and ensure comfort, reducing energy consumption and promoting net zero environmental impacts.

Historical background of bio-inspired designs

Bio-inspired design have a long history. Greek and Roman architecture both used Corinthian columns that were inspired from acanthus leaves which can be seen in ancient structures like Temple of Olympian Zeus, Greece (2nd century AD) and Pantheon building, Rome (27 B.C.E) respectively. Gothic architecture used both ornamental fan vault inspired from the structure of the tree used in buildings like Rosslyn chapel, Scotland (mid-15th century) and Gloucester cathedral, England (14th century) and flying buttresses in Notre Dame Cathedral, Paris (1163). These all are examples of bio-inspiration in ancient times (SabryAziz & sherif, 2016).

Leonardo da Vinci (1452-1519) is considered to be the first pioneer of the bio inspired designs. The anatomy and flight of birds were closely examined by him in his futile attempt to create a "flying machine." While he never built a functional flying machine but his sketches and notes laid the groundwork for further aviation pioneers. Later, Janine Benyus (1992) introduced term bio-inspiration in the book 'biomimicry: innovation inspired by nature 'to a wider audience (Massimoa, et al., 2017). Many authors like Gruber and Gostonyi (2010), Garbuio Massimo (2017), Heerwagen (2003), M. Pedersen Zari (2009), talked about the term bio-inspiration in the built environment.

Bio-inspired Design in Contemporary Developement Scenerio

The technique of using biological systems as a source of inspiration to solve problems for people, develop cutting-edge technology, or produce more effective and long-lasting solutions is known as bioinspiration. Many researchers working on bio-inspired architecture acknowledges that resources are limited, the environment is fragile, and other living things are just as significant as humans. The concept of natural equilibria serves as a vantage point for bioinspired design, which advances a novel, sustainable and more comprehensive viewpoint (Massimoa, et al., 2017). Bio-inspiration has two major aspects- Biomimetics and Biophilic (Heerwagen, 2003). These two aspects have been described in detail in the section 3.1 and 3.2.

Biomimetics in Façade Designing

The study of biological systems, procedures, and prospective technological applications is referred to as "biomimetics". It involves the imitation of an organism's shapes, materials, construction techniques, operations, or activities, as well as behaviour of an organism or an entire ecosystem (Ball, 2001). The organism's adaptability to environmental changes has sparked interest in creating new technologies notably in building facades, to enhance energy performance (Avcioglu & Basak, 2020). Three main reasons to investigate biomimicry in façade architecture are as under:

- First is biomimicry for invention, which involves studying biological processes to develop modern technologies in façade.
- Second driving force is sustainability through biomimicry in façade designing.
- The final driving force is using biomimicry to improve user psychological wellbeing (Khelil & Zemmouri, 2018).

Biomimetics Adaptive Building façade

Façades are key building skin components promoting external architectural characteristics of the building. The purpose of the façade is evolving from 'passive shielding covering to active regulator of a building's energy balance' (Faragalla & Asadi, 2022). Bio-inspired facades on the other hand integrate natural design principle and pattern to create building exteriors that mimics and harmonize with the surrounding environment. In terms of indoor environment needs, there are four façade performance indicators for bio-inspired facades that are described below -

- Biological factors - By altering inside lighting and thermal settings, the facade should respond to the user's hourly/seasonal needs.
- Climatic factors - Adaptation to the external environment is critical. Humidity, wind, sun radiation, and precipitation are the key climatic elements.
- Biophilic factors – These factors include visual and non-visual features, acoustic features, shape and form and color and material.
- Energy Factors – The indoor environmental conditions like heating and cooling requirements consumes higher energy requirements. This should be maintained sustainably as most of the

transmission of heat and light occurs through the façade of the building (Parsaee, et al., 2021).

Biomimetics adaptive building facade specifically defined as façade system that respond to different circumstances around the environment by changing its morphological, behavioural and physiological properties that are inspired from the biological systems of the nature to meet functional requirements of the buildings and enhances its performance (Faragalla & Asadi, 2022). There are three levels of biomimetic approach in façade designing i.e. physiological and functional level, morphological and structural level and behavioural level. The morphological and structural level has been maximum explored and implemented in the built environment. The behavioral level i.e. organism-environment interactions also consist of few typologies based on sensors integrated into the façade whereas physiological level has not been explored much. These three levels are briefly described below-

- Functional and Physiological level - This investigates all the chemical reactions which happens within the body of organism.
- Morphological and structural level - The morphological or structural level of an organism's physical features like form and pattern allow it in responding to specific limitations of environment.
- Behavioural level- It is significant to note that the degree of biomimetic behaviour depends on how an organism engages with its surroundings, often through processes that ensure survival (López, et al., 2017).

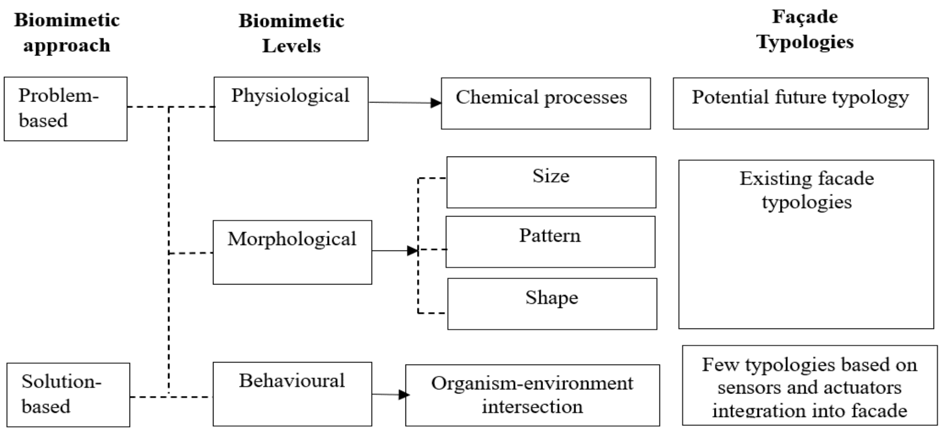

Figure 1: Structure for Biomimetics Design of Building Façade

Functional Comparison Between Skin of Organism and Building Facades

Nature and architecture are related because each change and adapt to its environment, much like a building should. The building envelope works as a conduit heat transfer between the internal and external environments, of the structures and their surroundings through conduction, convection, radiation, and evaporation. Nature offers additional outstanding thermoregulation strategies to learn from in this circumstance. (Badarnah, et al., 2010). Through behavioural and physiological means, organisms can even regulate their body temperature. Furthermore, in order for organisms to survive the harsh environmental circumstances, they must maintain the temperature of the body within a very narrow range. All these can act as inspiration for the designers and the engineers in the designing process (amei & Vrcelj, 2021).

Skin-building methods are one of the ideas utilized to develop the connection between an organism and a structure. In this sense, the façade of a building is viewed as the skin or thin membrane that covers the structure and controls its mechanical and electrical operations as well as defining its internal areas, much like the skin of a living creature. Furthermore, both types of skin have a number of layers that act as particle filters as well as sensitive receptors for heat, pollution, water pollution, and noise pollution. One of their key points of similarity is that both forms of skin maintain the state of interior areas while fulfilling the requirements of the inner space or body. (amei & Vrcelj, 2021).

Table 1: Comparison between the skin of organisms and analogies in façade architecture

ACTIONS	SKIN FUNCTION IN ORGANISMS	BY/WHAT	ARCHITECTURAL ANALOGY IN FACADE
Construct	Provide structure	Shell/internal structure with soft body and skin	> building construction
Exchange	Protect and enclose inner organ Mechanical protection Self-healing Protection from radiation Protection of dirt protection of microorganisms production of insulation	Soft or tensioned skin Surface characteristics, chemical action Outer layer (hair, feathers)	>membrane system > hard outer layer >self-healing material >UV protection >self-cleaning >oxidation surface >thermal insulation
Exchange	Sensing Harvesting of energy Control air exchange Thermoregulation Regulation of circulation Interchange of substances, prevent loss Water and humidity sweating	Diverse information Thermal, solar energy Oxygen, CO2 Nutrients Water	>sensors >solar systems >diffuse systems >thermal balance >filter system >cooling
Signal	Appearance in environmental signaling	Color pattern, color change etc.	> communication
Store	Storage of energy Storage of chemical energy Storage of humidity	Thermal energy, fat and sugar	>heat storage >energy storage >water storage

Reference: (Gruber & Gosztonyi, 2010)

Biophilic in Façade Designing

The second major aspect of bio-inspiration is biophilic. Biophilic is a sustainable building design approach that connects humanity with the nature, supporting their health, productivity and well-being. It enriches the built environment and promote positive interaction with the nature, resulting in positive environmental impact (Berkebile et al., 2008). The three categories of biophilic design are 'nature in the space, nature analogue and nature of space patterns' are shown in table below:

Table 2: Three categories of Biophilic design

Nature in the space	Nature analogues	Nature of space patterns
It includes direct relationships with the natural components.	It discusses indirect, biological, and non-living natural references.	It describes how human behaviors and emotions are influenced by architectural design on psychological level.
A visual connection to nature. A non-visual connection to nature. Sensory stimuli that are not rhythmic. Variability in thermal and airflow. The presence of water. Light that is both dynamic and diffuse. Relationship with natural system.	Biomorphic patterns & forms. Tangible relationship to nature. Order & complexities	Prospect. Refuge. Mystery. Risk.

Implementing biophilic principles in façade designing involves incorporating natural elements and patterns to create a connection between the built environment and nature. To achieve this, designers can use materials such as wood or stone, integrate green walls or vertical gardens and incorporate patterns inspired by nature in the façade. Maximizing natural light through large windows and creating views of green spaces also contribute to biophilic design. A notable example is the Bosco Verticale (Vertical Forest) in Milan, Italy, this residential complex features high-rise towers covered with a variety of trees, plants and shrubs on its facades. The lush greenery not only creates an aesthetically pleasing appearance but also contributes to improved air quality, reduced noise and connection to nature for the resident.

Case studies and design parameters for bio-inspired facades

Because façades function under the impact of climatic conditions and influence the inner living environment, the major criteria for a sustainable façade are often material and energy efficiency. An organic skin would be treated as being moved by natural processes like wind, light, rain, drought, snow, and many more in a sustainable design problem. It can also perform other life-sustaining duties including as breathing, carbon collection, and water balancing, which generally need multiple layers. Energy demands, functional factors, and structural efficiency all should be considered when designing a more sustainable façade. (Tokuç & Özkaban, 2018). A sustainable façade may be non-toxic, water resistance, water storage, self-healing, self-cleaning, insulation storage, frost resistance, controlled reflectant, carbon regulatory and adaptable. Traditional facades lack all these multifunctional features. The three primary criteria for a Bio-inspired façade designing are "energy needs," "form and structure," and "sustainability considerations" (Tokuç & Özkaban, 2018). These three criteria of bio-inspired facades are explained in below mentioned case studies-

Media -TIC Building (Barcelona, 2009)

Media-TIC, an office building in Barcelona, uses ETFE (ethylene tetrafluoro ethylene) facades to block UV radiations and adjust to changing weather patterns. The building features 104 inflatable cushions with three chambers, providing thermal insulation and solar radiation regulation. The air is controlled separately by a lighting sensor, and the southwest façade offers shade from two sheets of ETFE (ethylene tetrafluoro ethylene) laden with nitrogen and oil coalescence. The building design reflects changing weather patterns and air density. The project uses 2500 m2 of breathing inspired ETFE (ethylene tetrafluoro ethylene) cladding in total, saving 20% on energy. Because of the nonstick surface, it doesn't require cleaning. It has been demonstrated to adhere to global fire safety regulations and doesn't produce smoke or aid in the spread of flames. the building achieved LEED Gold certification and reduced its emissions by 60%. The building received the World Building of the Year 2011 award based on its values of 1-20% CO2 reduction due to district cooling, 2-10% CO2 reduction due to its photovoltaic roof, 3-55% CO2 reduction due to dynamic ETFE sun filters, and 4-10% CO2 reduction due to energy efficiency related to smart sensors (Tokuç & Özkaban, 2018).

Figure 2: South -East Façade with ETFE cushions

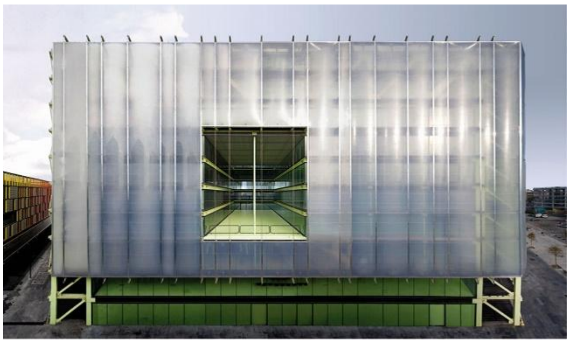

Figure 3: South -West Façade with ETFE and nitrogen

BIQ (Bio-Intelligent Quotient) Apartment Building (Hamburg, Germany, 2013)

The 2013 BIQ apartment complex in Hamburg, Germany, designed by the engineering firms named Arup and Splitterwerk, are the first to use photo-bioreactors in building façade. "Building with a Bio-Intelligent Quotient," or BIQ for short, is a five-story, cubic building. The algae act as a partition between the inside and outside of the building and transfer thermal warming and biomass. (Tokuç & Özkaban, 2018).

The 200 m2 façade is made up of 129 (2.5 x 0.7) m photo-bioreactor panels. The algae with liquid nutrients and CO2 is consistently supplied by a water circuit that runs through the whole façade. The panels gather light that is not required for the algae and use it as solar thermal collectors. The gathered day-light is subsequently converted into heat using heat exchangers. The light beams are absorbed by the façade, much like a solar thermal unit, and produce heat that is either used right away for water heating, or can be stored below via boreholes. When the algae are ready to be gathered, they are taken to the technical room of the building as a thick pulp, where they are fermented by biogas plant. The effectiveness of these algae façade elements was evaluated for a year. The average daily production of biomass from the façade was 15 g, which was stored next to the biogas generator. Moreover, it produced 30 kWh/m2 of biomass and 150 kWh/m2 of thermal energy. The building's annual CO2 emissions were thereby reduced by 6 tons.

Figure 4: South -East Façade with algae façade

Shibori Office (Gandhinagar, Gujarat, 2021)

The Grid Architects designed an 1890 sq. foot office in Gandhinagar, Gujarat, India. With its distinctive red terracotta concrete facade and circular cutouts that let light and shade play throughout the day, Shibori is a fascinating location to work. The bigger cutouts are at the bottom and the smaller ones are at the top which allow controlled solar-light. The office's biophilic design features also include large windows, planters, and courtyards in addition to this screen, promoting a unique spatial experience with moderate natural light, promoting vibrancy, energy and productivity (Abdel, 2021).

Figure 5: Front Façade with Circular Cuts,

The three cse studies of bio-inspired façade based on three main features of designing a sustainable façade i.e. form and structure, energy requirement, and sustainability considerations have been presented. First two case studies Media – TIC building, Barcelona (2009) and BIQ (Bio-Intelligent Quotient) apartment building, Germany (2013), are biomimetics in nature and Shibori Office, Gandhinagar, Gujarat (2021) is biophilic in nature.

Results and discussions

According to the United Nations Environmental Programme (UNEP) global status report 2022, Building energy demand increased by about 4% from

2020 to 135 EJ (Exajoule), the largest rise in the previous ten years. CO2 emissions from building operations have reached an all-time high of around 10 Gigatons CO2, signifying a 5% rise over 2020 and a 2% increase over the previous peak in 2019. Hence, sustainability in façade designing by adopting bio-inspiration principles is the need of an hour. Nature demonstrates effective tactics, which in return provides a wide database for adoption strategies. Architects are required to apply these adoption strategies from nature to designing façade. This study has provided three contemporary examples of bio-inspired façade based on three main features in designing a sustainable façade are form and structure, energy requirement and sustainability considerations.

Energy Requirements- Climate change is crucial in the designing of facades, which control weather elements like solar radiation, interior temperature and wind speed. Innovative solutions like sun orientation, shading and insulation are used. Thermal comfort in facades is determined by material properties and heat balance. Nowadays, Facades can even generate renewable energy. Some façades can cultivate algae that can develop oil for biomass, biodiesel, bioethanol, or bio-hydrogen production (Poppinga, et al., 2017).

Form And Structural Efficiency- Nature has significantly influenced structural systems throughout history, with prototypes ranging from insect mounds to spider web, honeycombs and biomimetic technique. Mimicking the efficient load distribution and material use found in biological structures, Bio-inspired facades achieve greater resilience and sustainability. Nowadays, digital technology enables parametric growth principles for complex geometries in façade designing, allowing for efficient construction using CNC or 3D printing, while preserving biomimetics features and reduce carbon footprint (Tokuç & Özkaban, 2018).

Sustainability Consideration- Resource efficiency is a crucial aspect of architectural process, reducing environmental impact and ensuring no natural resources go to waste by using outcomes for other actions (Benyus, 2002). Building exteriors consider biological performance, flexibility, breathability, low energy content, carbon sequestration, air purity, water efficiency and sensory capacities while designing sustainable bio-inspired façade (Tokuç & Özkaban, 2018).

First case study is breathing inspired Media – TIC building, Barcelona (2009), is energy efficient and has properties of self-cleaning, providing thermal insulation and solar radiation regulation. Second is BIQ (Bio-Intelligent Quotient) apartment building, Germany (2013), uses algae that produces biomass to generate electricity. Third is Shibori Office, Gandhinagar, Gujarat (2021), consisting parameters of biophilic architecture. Detailed comparison among the three case studies on several different parameters is mentioned below:

Table 3: Comparative Analysis

Sr. no	Building name	Key aspect	Façade inspiration and material	Façade indicator	Properties of façade material	Façade sustainable features
1	Media-TIC Building, Spain (2009), office building	Biomimetics	Breathing inspired ETFE (Ethylene fluoro ethylene) cushions used.	Climatic factors	1. Nonstick surface hence, doesn't require cleaning 2. It has an 85% ultraviolet coefficient. 3.Density: 350 g/sq.m 4. Good flexibility 5. Able to elongate and transform into any geometric shape	1 The project uses 2500 m2 of ETFE cladding in total, saving 20% on energy. 2. 3-55% CO2 reduction because of dynamic ETFE sun filters, and 4-10% CO2 reduction because of energy efficiency related to smart sensors. 3. Achieved LEED Gold certification and award - World Building of the Year 2011

2	BIQ (Bio-Intelligent Quotient) Apartment Building, Germany (2013)	Biomimetics	Algae as a source of inspiration to develop energy. Photobioreactors panels used	Energy factors	1. Algae can be cultivated in photo-bioreactors 2. The façade is made up of flat plate photo-bioreactor panels, which have a high UV light transformational efficiency	1.The façade produced 15 g of biomass per day on average, which was kept next to the biogas generator. 2. Furthermore, it induced 150 kWh/m2 of thermal energy and 30 kWh/m2 of biomass. As a result, the building's yearly CO2 emissions were decreased by 6 tons
3	Shibori Office, Gandhinagar, India (2021), office building	Biophilic	The Japanese resist dyeing process distinguished by circles and circular patterns. Terracotta used.	Biophilic factors (dynamic and diffuse lights)	A red terracotta concrete exterior with circular cutouts allows for a play of sunlight and shade throughout the day	1.Perforated skin that works as a sun-breaker while also creating a dramatic play of light and shadows inside. The circular cuts are a perforated envelope that attracts solar light and generate patterns that perform massive drama throughout the day. 2.Materials, textures, and color all contribute to the story in concert with the sunshine, adhering to biophilia principles

CONCLUSION

Bio-inspiration particularly biomimetics has been employed in architecture design to a restricted way (Nessim, 2001). Although organisms might provide inspiration for technological applications, their anatomical and functional designs aren't always the best fit for a particular situation or environment. Only a small amount of biomimicry has been used in architectural design to date. More than 70 bio-inspired building façade case studies have been reported during the past 20 years, and the industry is developing new typologies at a rapid pace. (Hubert, et al., 2022). Out of the three levels of biomimetic approach in façade designing explained in section 3.1.1, the morphological level and behavioral level have been maximum studied and implemented in the built environment while physiological level has not been explored much, so there is wider scope to develop potential façade typology based on this level. Extensive study is necessary to validate bio-inspired strategies in façade designing, their applicability in the construction industry, and the appropriate scales. This is a time-consuming process since active materials research is required to obtain testing findings in order to efficiently transfer biological techniques into technology solutions.

The ideas of sustainability and bio-inspiration are complementary. But not all applications of bio-inspiration are sustainable. Some bio-inspired facades may prioritize aesthetics or functionality without considering overall ecological impact. For instance, using exotic or rare materials inspired by nature can contribute to resource depletion and environmental harm. Additionally, complex technological solutions mimicking natural processes may have a high energy and resource demand during production and maintenance.

It's crucial to assess the life cycle and overall ecological footprint to ensure they align with sustainability goals. In facade architecture, sustainability is typically understood to mean using resources efficiently, reducing pollution, and lessening the influence on natural ecosystems. However, one may argue that planetary health and human health are inextricably linked. Such knowledge serves as the cornerstone of a sustainable design methodology (Zari, 2009).

CONFLICTS OF INTEREST

No conflicts of interest were declared by the authors.

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Passive Design Techniques in Net Zero Building

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Abstract— To achieve net-zero energy buildings and bring in a new age of sustainable architecture, this research paper explores the field of passive design solutions. This research paper investigates the value of passive design strategies in achieving net-zero energy buildings. The efficiency of passive design techniques, such as thermal mass, insulation, daylighting, natural ventilation, and orientation, is investigated in this research. The report emphasizes the importance of these measures in lowering energy consumption and minimizing environmental effects by examining case studies of successful net-zero buildings. Emerging potential including building material developments and integration with renewable energy sources are considered with the problems of technology limits and financial consequences. The importance of passive design in sustainable building is emphasized in the paper's conclusion, along with some useful suggestions for the next architectural techniques. The recommendations include cooperative efforts to promote supporting building codes, the smooth integration of innovative building materials, and the synergy between passive design and renewable energy. The architectural community can make a substantial worldwide contribution to a resilient and sustainable built environment by implementing these tactics.

Keywords: Net-Zero Building, thermal mass, daylight, ventilation, orientation

INTRODUCTION

India's net-zero objectives need to be supported by robust energy efficiency initiatives, including daylighting and lighting controls, low-energy comfort systems, adaptive thermal comfort standards-embracing design, efficient equipment and systems, and—above all—user acceptance and behavior modification towards a sufficiency-based lifestyle. Even if establishing minimum energy performance standards for buildings will help reduce the rising energy demand, setting net-zero targets is equally vital for our energy security going forward. (USAID) - United States Agency for International Development, 2015 It's also essential to have a fully functional smart grid program, renewable energy policies that help achieve net-zero energy, demand response-ready equipment, and performance benchmarking. National and international experts from the US, EU, and Asia convened at the first Net Zero Energy Buildings (NZEB) International Seminar in India in 2013 to assess the barriers to the widespread adoption of NZEBs in that country and to test solutions that could be replicated there with some local context adaptation. A NZEB Knowledge Portal was also created in collaboration with program partners BEE, and industry professionals actively took part in the establishment of a NZEB Alliance. NZEB performance indicators were most prominently added to the Energy Conservation Building Code in its 2017 iteration. The establishment of NZEBs in India's leading framework for developing energy-efficient policies made this achievement noteworthy. BEE is constantly working to increase

NZEB's visibility. The National Mission for Enhanced Energy Efficiency (NMEEE), which is a component of India's NDC, seeks to develop the energy efficiency sector by establishing a supportive regulatory and legislative framework. It aims to step up initiatives to open up the market for Net Zero and energy efficiency. (USAID, the United States Agency for International Development) (2015).

Building sector energy consumption

In India, buildings use thirty-three percent of the country's electricity. Seventy percent (about 700–900 million square meters per year) of the building stock needed by 2030 is still unbuilt. According to the U.S. Energy Information Administration's International Energy Outlook 2017 (IEA 2017), some coal usage will be replaced as India's electricity consumption rises from 59% in 2015 to 65% in 2040. According to IEA 2017, from 2015 to 2040, home electricity consumption will rise twice as quickly as the overall residential sector's energy consumption. By 2040, 68% of the energy supplied to Indian homes will be electricity, up from 46% in 2015. (Abdellah, 2019) India's building energy consumption has been rising due to several factors including rapid economic growth, rising income, urbanization, and population growth. As a result, the country's infrastructure, which depends heavily on fossil fuels, is under strain and its dependence on imports of fuel is further increased. Nation-states worldwide are addressing two issues at once:

1. Adopting near-zero or net-zero objectives to reduce the energy consumption and carbon emissions of its collection of buildings. Zero methods often focus on reducing the impact of the resource use cycle, including the footprints of water, energy, materials, transportation, and waste. (Abdou & Mghouchi, 2021)They do this by taking a systems approach. But as intense energy usage is now thought to be the main cause of climate change, achieving net-zero "energy" or "carbon" targets is becoming more important.

2. Moving toward the future of a decentralized, digital, and carbon-free grid. Changing the nation's energy mix involves updating the targets for renewable energy. (Alajmi, Rodrígueza, & Sailor, 2018)The system becomes more flexible when it prioritizes renewable energy. Today, various nations are creating and experimenting with their economic models to meet the needs of flexible grid services, including building-based services.

The only area where building energy demand and grid services have not yet been discussed together is renewable energy. Nations all across the world are starting to understand that buildings constitute a crucial last-mile link to the future grid and that the flexibility provided by equipment and structures represents an unrealized opportunity. (Charron & Athienitis, 2006) A platform called "Zero-In" broadens the conversation around "Net Zero" buildings to include "High-performing, smart, connected, and flexible" constructions that have less of an impact on the environment.

Importance of achieving net-zero energy buildings:

Achieving net-zero energy buildings is crucial for promoting environmental sustainability and thwarting climate change on a worldwide scale. To balance the amount of renewable energy produced on-site with the total energy consumed within a structure, net-zero energy buildings offer a paradigm shift in the way we approach construction and energy usage. This objective is significant in many ways. First off, by reducing greenhouse gas emissions, net-zero energy buildings help to lessen the influence of the built environment on climate change. Second, they show that it is possible to meet the demands of modern living without draining limited resources by acting as models of energy efficiency. (Elaouzy & Fadar, 2022) Net-zero energy buildings also promote resilience against energy interruptions by lowering dependency on conventional power networks, which furthers their contribution to energy independence. From an economic perspective, these structures frequently lead to lower long-term energy bills for owners and tenants. Net-zero energy building development is generally in line with a larger goal of developing resilient, sustainable, and ecologically conscious communities for both the present and the future. (Fengb, Zhang, & Jia, 2019).

LITERATURE REVIEW

Net zero energy buildings, or almost zero energy buildings, are energy-efficient structures with shallow energy demands that are satisfied by renewable energy sources. Annually, these kinds of buildings generate as much energy as they use. (United States Agency for International Development (USAID), 2015)NZEBs must use energy-efficient technologies to drastically reduce energy consumption before turning to renewable energy sources (RES) to cover any remaining demand if they are to meet their net zero energy targets. Efficiency improvements in these buildings allow renewable energy solutions to meet the remaining energy needs. This makes the most sense in terms of achieving the NZEB goal.

Annual Electricity Consumption; Gilijamse, 1995

“A zero-energy house is one where the annual output of electricity is equal to the annual consumption of electricity and no fossil fuels are used. The power grid functions as a virtual buffer with yearly balanced delivers and returns, in contrast to the autarkic scenario"

Energy use; Torcellini et al., 2006

"A residential or commercial building that achieves net zero energy status (ZEB) has significantly decreased its energy requirements through efficiency gains, allowing renewable technologies to meet the remaining energy needs"

Scope Boundary; Laustsen, 2008

"Zero Net Energy over a year, buildings become neutral, which means they provide the same amount of energy to the supply grids as they take out of them. In this sense, they don't use fossil fuels for anything like lighting, heating, or cooling, however, occasionally they do use grid electricity"

On-Grid ZEB; Gilijamse, 1995; Parker, et al., 2001; Iqbal, 2003; Laustsen, 2008

"Zero Net Energy over a year, buildings become neutral, which means they provide the same amount of energy to the supply grids as they take out of them. In this sense, they don't use fossil fuels for anything like lighting, heating, or cooling, however, occasionally they do use grid electricity"

On-site supply; Torcellini, et al., 2006

"Utilize the renewable energy sources—photovoltaic, solar hot water, and wind—that are located within the building's footprint. Make use of the on-site renewable energy sources, such as solar hot water, wind, PV, and low-impact hydro, but avoid using them on the building"

Passive Design Strategies:

Daylight

Daylighting is a basic passive design technique that maximizes natural light to lessen the amount of artificial lighting a structure needs. A well-thought-out daylighting system can lower energy usage dramatically, improve indoor air quality, and improve visual comfort. (Harkouss, Biwole, & Fardoun, 2018) To maximize natural light penetration and minimize heat gain and glare, key considerations include the positioning of windows, skylights, light shelves, and reflective surfaces.

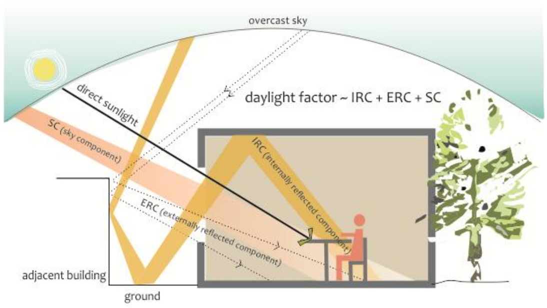

Figure 1: Daylight factor is used for determining daylight, reference: (United States Agency for International Development (USAID), 2015)

Benefits:

- Enhances occupant well-being, productivity, and mood.
- Reduces dependence on artificial lighting, saving energy.
- Promotes a visually appealing and dynamic indoor environment.

Challenges:

- Glare and excessive brightness may pose discomfort.
- Designing for daylight requires careful consideration to balance light distribution.
- Variability in natural light availability due to weather conditions.

Technologies and Design Considerations:

- Light Shelves and Reflective Surfaces: Redirect sunlight deeper into the building.
- Automated Shading Systems: Control light levels and mitigate glare.
- Skylights and Clerestory Windows: Introduce natural light from above.

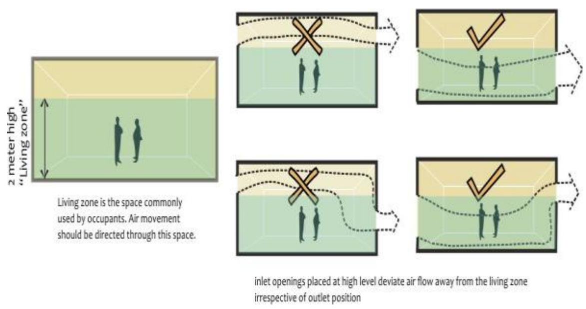

Figure 2: Schematic diagram of a compression refrigeration cycle, reference: (United States Agency for International Development (USAID), 2015)

Natural Ventilation

To control interior air quality and temperature without the use of mechanical systems, natural ventilation uses prevailing winds and temperature differentials. (Harkouss & Fardoun, 2018) Using windows and vents as examples, this tactic entails placing them in key locations to allow fresh air to enter and expel. In addition to improving passenger comfort and well-being, natural ventilation also lowers energy consumption.

Principles:

- Utilizes natural airflow and pressure differentials.
- Inflow of fresh air and outflow of stale air through strategically placed openings.
- Reduces the need for mechanical ventilation systems.

Effectiveness:

- Enhances indoor air quality and occupant comfort.
- Lowers energy consumption associated with mechanical ventilation.
- Can be effective in a variety of climates, when appropriately designed.

Thermal Mass

Thermal mass is the process of absorbing, storing, and then releasing heat through the use of high-density materials like masonry or concrete. Reducing temperature swings aids in maintaining a steady indoor temperature. (Kang, Ahn, Park, & Schuetze, 2015) Thermal mass can be incorporated into a building's design to help with passive heating and cooling, which minimizes the need for mechanical systems and maximizes energy efficiency.

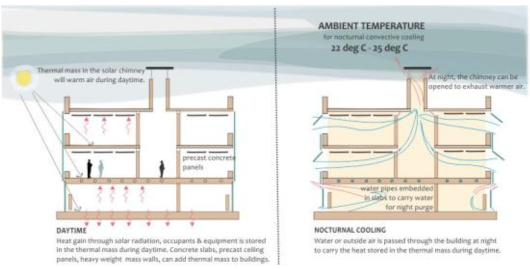

Figure 3: Thermal mass, reference: (United States Agency for International Development (USAID), 2015)

Role in Temperature Regulation:

- Thermal Inertia: Absorbs and stores heat during the day, releasing it at night.
- Stabilizes Indoor Temperatures: Reduces temperature fluctuations.
- Passive Heating and Cooling: Contributes to a more comfortable indoor environment.

Materials and Construction Techniques:

- High-density Materials: Concrete, masonry, or phase change materials (PCMs).
- Exposed Thermal Mass: Incorporates thermal mass into the interior design.
- Night Ventilation: Capitalizes on cool nighttime temperatures to pre-cool the thermal mass.

Insulation and Building Envelope:

Reducing heat transfer between a building's exterior and inside requires both insulation and a well-thought-out building envelope. (Lan, Wood, & Yuen, 2019) An airtight building exterior and adequate insulation assist in controlling indoor temperatures, which lowers the need for excessive heating or cooling. This tactic is essential for improving energy efficiency and guaranteeing occupant thermal comfort.

Impact on Energy Efficiency:

- Minimizes Heat Transfer: Reduces heat gain in summer and heat loss in winter.
- Airtight Envelope: Prevents air leakage and enhances thermal performance.
- Optimal Window-to-Wall Ratio: Balances natural light and insulation.

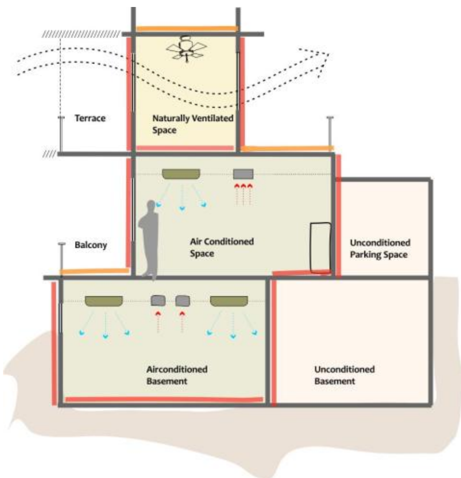

Figure 4: The figure above shows the insulation position, reference: (United States Agency for International Development (USAID), 2015)

Innovative Materials and Practices:

- High-performance Insulation: Expanded polystyrene (EPS), polyurethane foam.
- Double-Glazed and Low-E Windows: Enhances thermal resistance.

- Thermal Breaks in Framing: Reduces heat transfer through window frames.

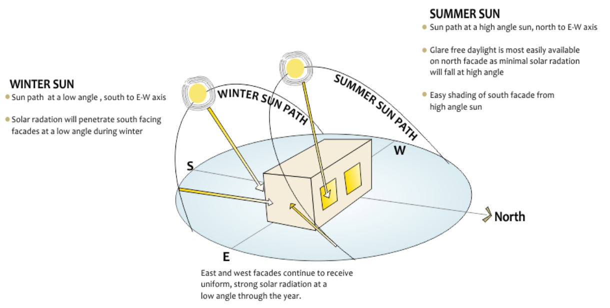

Figure 5: Orientation, reference: (United States Agency for International Development (USAID), 2015)

Orientation and Site Planning:

A building's orientation and site planning are crucial to its energy efficiency. When oriented properly, one can minimize exposure to adverse conditions and optimize exposure to sunshine for passive heating. (Musall, Weiss, & Voss, 2002) Careful site planning takes into account elements like solar access, prevailing winds, and vegetation to maximize building efficiency and reduce energy consumption.

Optimizing Solar Gain and Minimizing Heat Loss:

- Solar Passive Design: Aligning the building to maximize solar exposure.
- Deciduous Plantings: Provides shade in summer and allows sunlight in winter.
- Building Shape: Minimizing surface area exposed to extreme weather conditions.

Site-Specific Considerations:

- Local Climate Analysis: Understanding regional weather patterns.
- Wind Studies: Identifying prevailing winds for natural ventilation.
- Topography and Microclimate: Incorporating natural features for optimal site utilization.

High-performance Windows:

Reduced air leakage, reduced solar radiation, and minimal heat gain or loss are all goals of high-performance windows. (Omrany & Marsono, 2016) Energy-efficient glazing materials and creative frame approaches enhance the total thermal efficiency of windows. Energy conservation, daylighting, and indoor comfort are all improved by carefully choosing the proper kind of windows and positioning them inside the building envelope.

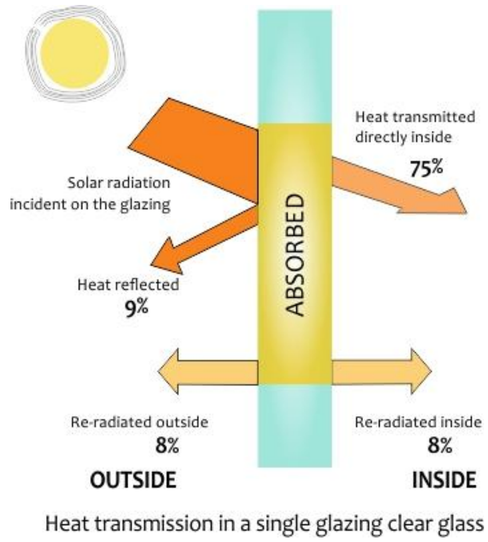

Figure 6: Fenestrations (windows, skylights, & and other openings in a building, etc.), reference: (United States Agency for International Development (USAID), 2015)

METHODOLOGY

The study follows an organized methodology and begins with a comprehensive review of the literature to understand the principles of passive design. A range of case studies are selected, and a mixed-methods approach is employed, incorporating reports, research papers, surveys, and trustworthy websites. Quantitative data on energy consumption and building measures is collected, analyzed statistically, and compared among case studies. The purpose of the results synthesis is to arrive at well-considered conclusions regarding the effectiveness of passive design in achieving net-zero energy buildings. This clear-cut and exact method ensures a comprehensive analysis of the research questions within the parameters of the study.

CASE STUDIES

Atal Urja Bhawan, New Delhi (year of completion 2022)

A net-positive energy building functions as the headquarters of the Ministry of New and Renewable Energy (MNRE). Recognized by GRIHA, the building serves as an exemplary government office building.

Figure 7: Atal Urja Bhawan, New Delhi, reference: (United States Agency for International Development (USAID), 2015)

Passive Design Strategies, The main entrance of the building is located in the center of an atrium that runs north-south through the structure. To optimize natural light coming from the north, the south wing has been tilted. The building's layout is divided into two halves by a central corridor, with services facing west to shield inhabited areas from the intense west sun and functional spaces facing east. This tactic successfully resolves the issue raised by the site's north-south orientation. The building's west facade is a monolithic mass with cross-ventilation-enabling GFRC jallis covering apertures. A double wall with ACC construction serves as thermal insulation on the east face. Insulation made of 200 mm-thick glass wool fills this hollow wall. In addition to providing shade for the building facade, the south wall acts as a solar wall, producing power on-site. To optimize natural light, give superior views, and offer seclusion from public activity below, the offices are situated on the third through eighth floors. The east and north facade openings have a double-glazed unit (DGU) system. This provides insulation and lets natural light into interior areas. The landscape is made up of newly planted native and local trees mixed with older, conserved trees. Trees line the paths that lead to the building's entrance. (United States Agency for International Development (USAID), 2015)

Indira Paryavaran Bawan, New Delhi

Indira Paryavaran Bhawan, the new office building for the Ministry of Environment and Forest (MoEF) is a radical change from a conventional building design.

Figure 8: Indira Paryavaran Bawan, New Delhi, reference: (United States Agency for International Development (USAID), 2015)

PassiveDesign Strategies, A large central courtyard and several blocks connected by halls face both north and south of the structure. The optimal proportion of windows to walls diminishes heat penetration. Over 50% of the structure's exterior is covered in plantations. Pathways and circulation roadways are soft-paved to facilitate groundwater recharging. There is less need for artificial lighting because 75% of the building's floor area is naturally lighted. As a light well, the inner courtyard is used. The stack effect causes natural ventilation, which facilitates airflow in the central courtyard. To increase cross ventilation, use jaalis and windows. (United States Agency for International Development (USAID), 2015)

Materials and methods of construction, AAC blocks made of fly ash, plaster and mortar made of fly ash, stone and ferro cement jaalis, locally made stone flooring, Composite bamboo jute doors, frames, and floors, glass with high efficiency, low SHGC, low VLT, and low U-value that has been optimized with the right shading Shelves with lights to provide soft sunlight.

Bhawar Residence, Chennai, Tamil Nadu (year of completion 2023)

Bhawar House in Chennai is an innovative residential building that is notable for its low energy requirements and passive design strategies. Nine people can live in the three-story house, which features a symphonious atrium connecting the volumes.

Figure 9: Bhawar Residence, Chennai, reference: (United States Agency for International Development (USAID), 2015)

Passive Design Strategies, The aerodynamic features of the structure were used to modify its massing to reduce heat uptake from solar radiation and enhance natural ventilation. Reorienting the floor plates by 12 degrees clockwise and creating transitional spaces such as terraces and lobbies to allow indirect sunlight inside would help enhance the venturi effect in the central atrium. A 500mm radius was applied to the building's corners to facilitate easy airflow. The straight wall was broken and a bridge was built to span the space between the two sides of the house to create the lobby, which allowed for ventilation. The perforated screens on all four faces with integrated plants create a reverse venturi effect that increases air velocity. The home's architecture includes a central atrium on purpose to ensure that all frequently used areas have enough natural light. On each of the four facades, windows have been carefully placed to maximize natural light and minimize glare. (United States Agency for International Development (USAID), 2015) Thirty-five percent of the site's open space is soft-paved with perforated grass cells to add more vegetation. White lantanas and spider lilies add to the ground cover's greenery. Drought-tolerant plants such as spider lilies, lantana, jasmine polyanthum, vernonia creeper, and adenium can be found throughout the terrain. Hydrophilic felt, which shades the balconies, is made entirely of recycled materials for the vertical green wall panels.

Avasara Academy Lavale, Pune (year of completion 2020)

Located in the rocky agricultural valley of Lavale, Maharashtra, Avasara Academy is a residential school complex made up of six similar buildings, each housing a teacher home and a student dormitory on levels three and four and classrooms on levels one and two. Simplicity, functionality, sustainability, affordability, affordability, aesthetics, visual excitement, and inclusivity characterize its rigorous architecture.

Figure 10: Avasara Academy Lavale, Pune, reference: (United States Agency for International Development (USAID), 2015)

Passive Design Strategies, The six four-story rectangular blocks follow the hillside's undulating curves, taking note of the best views and arranging themselves in the most advantageous orientation. The walkways, courts, gardens, and terraces on the campus are arranged in an unofficial yet interconnected manner. The building's design skillfully arranges the volumes about overhangs and shadows, articulating straightforward reinforced concrete structures while laying the groundwork for a passive climate strategy. Prefabricated structural ceilings and a skeletal structure with reinforced concrete floors are examples of articulated concrete construction. The building's interior, composed of locally sourced stone and raw concrete, functions as an inert thermal mass, absorbing solar thermal energy during the day and releasing it again the next morning. This process keeps the building's radiant temperature moderate and more stable. The structure blurs the boundary between openness and containment with its combination of glass surfaces, bamboo screens, and open areas. A second skin that unifies the architectural design, reduces glare, and adds a tactile element to the outside and interior through a beautiful play of light and shadow is deployed by the gently woven blades placed on the overhangs and the bamboo screen. (United States Agency for International Development (USAID), 2015)

Unnato Office Greater NOIDA, Utter Pradesh (year of completion 2018)

Located on a bigger 5-acre campus, Gainwell Commosales Pvt. Ltd.'s regional headquarters (North) is housed in the Unnati Office Building. As of 2018, it is the first building in India to be certified as Platinum LEED v4 BD+C: NC. The building performs 59% better than the average office building in the area, and 40% of its energy needs are met by on-site renewable energy generation.

Figure 11: Unnato Office Greater NOIDA, Utter Pradesh, reference: (United States Agency for International Development (USAID), 2015)

Passive Design Strategies, The three-story, cuboid-shaped building features a courtyard in the middle. It is oriented northeast-southwest, with the primary areas distributed in both directions. Passive design methods were used in the building's construction. The vegetation is a combination of ancient and new. Trees and other vegetation make up about 25% of the property's total undeveloped area. Only native plants have been planted to reduce the amount of irrigation water and pump energy used. Treated wastewater is utilized in irrigation. Ninety percent of the office areas have evenly distributed daylight, including the core and service parts. This is caused by the shape, the central courtyard, the shallow floor plates, the appropriate size, and the arrangement of the apertures. Every window has box shading built to cut down on glare. (United States Agency for International Development (USAID), 2015)

Pringapus 6&7, PT-Ungaran Sari Garments (PA6&7) Semarang, Indonesia (year of completion 2018)

Pringapus 6&7, often known as PA6&7, is a ready-made clothing factory in the Indonesian province of Central Java that is close to Semarang. The building is a part of PT Ungaran Sari Garments' current site, which also includes a canteen and five functioning manufacturing units (PA1–PA5). This is the company's first Indonesian plant that complies with international standards for environmental sustainability. PA6&7 is divided into two floors and has the same functional layout for the production of clothing.

Figure 12: Pringapus 6&7, PT-Ungaran Sari Garments (PA6&7) Semarang, Indonesia, reference: (United States Agency for International Development (USAID), 2015)

Passive Design Strategies, Planned originally was the building with the longer façade facing east-west. The design team debated for a long time before deciding to orient the longer facades north-south. The amount of diffused light from the north and the amount of direct heat gain from the west facade were successfully reduced by this project's southern hemisphere location. Two large, geometrically-defying courtyards were constructed for this building to accommodate a shallow floor plate. The structure features two exquisitely landscaped courtyards and is primarily rectangular. Longer facades that face both north and south, given the southern hemisphere location of the building, aid in mitigating direct heat gain, which mostly originates from the west facade, and allow for increased diffused light from the north. The courtyard design was enough to reduce the structure's initial 50 meters in depth to less than 30 meters. The building façade's design has optimized diffused daylight intake. Light shelves provide a more even and thorough dispersion of lighting by efficiently reflecting sunlight off their surfaces. The installation of a fixed ventilation louver system, both above and below the lintel level, has aided in creating comfortable indoor environments. With a view of the outdoors and access to daylight without glare, over 90% of the routinely used spaces are daylit. (United States Agency for International Development (USAID), 2015).

Table 1: Comparative Analysis:

Property	Atal Urja Bhawan	Indra Paryavaran Bawan	Bhawar Residence	Avasara Academy Lavale	Unnato Office Greater NOIDA	Pringapus 6&7, PT-Ungaran Sari Garments
Location	New Delhi	New Delhi	Chennai, Tamil Nadu	Lavale, Pune	Greater NOIDA, Uttar Pradesh	Semarang, Indonesia
Year of Completion	2022	N/A	2023	2020	2018	2018
Building Type	Government Office	Government Office	Residential	School Complex	Office Building	Manufacturing Plant
Certification	GRIHA	N/A	N/A	N/A	LEED Platinum (v4 BD+C: NC)	N/A
Energy Efficiency	Net-positive energy	Reduced artificial lighting	Minimal energy needs	Passive climate strategy	40% on-site renewable energy	International standards for sustainability
Orientation	North-South with tilted wing	North-South with central courtyard	Adjusted massing for solar gain	Hillside orientation	Northeast-Southwest orientation	North-South with longer facades
Daylighting	Central atrium for natural light	Inner courtyard for daylighting	Symphonious atrium for light	Locally sourced stone for thermal mass	Evenly distributed daylight in 90% of office spaces	Over 90% of routinely used spaces are daylit
Ventilation	Cross-ventilation, GFRC jallis	Natural ventilation, jaalis	Venturi effect, reverse venturi effect	Radiant temperature control through thermal mass	Box shading for reduced glare	Fixed ventilation louver system for indoor comfort
Construction Methods	ACC, glass wool, GFRC Wallis	AAC blocks, bamboo, high-efficiency glass	Aerodynamic shapes, bamboo jute composite doors	Reinforced concrete, locally sourced stone	Local flora, zinc panels	Courtyards to minimize direct heat gain
Landscaping	Native and local trees	Plantations, soft-paved paths	Green cover with native plants	Arranged in an interconnected manner	Native flora, wastewater irrigation	Manicured courtyards for diffused light

CHALLENGES AND OPPORTUNITIES

Technological Limitations:

The application of passive design techniques frequently faces obstacles because of the technology at hand. (Rodriguez-Ubinas, Monteroa, Porteros, & Vegaa, 2014) Modern systems that maximize passive heating, cooling, and ventilation may be difficult to acquire or finance in some areas or projects.

Impact:

- Slower adoption of advanced passive technologies in some areas.
- Potential compromise in achieving optimal energy efficiency.

Cost Implications:

For certain projects, the initial expenses linked with incorporating passive design techniques, such as energy-efficient windows, high-performance insulation, and renewable energy systems, may provide a financial obstacle. (Scognamiglioa &

Gardeb, 2014) For developers and homeowners, the first investment could seem excessive.

Impact:

- Hindered widespread adoption of passive design in mainstream construction.
- May lead to a perception that sustainable building is economically unfeasible.

Advancements in Building Materials:

Opportunities to get around technological constraints are presented by ongoing research and development in sustainable construction materials. (Shi, Wang, Huang, & Hong, 2019) More sustainable, long-lasting, and thermally efficient materials have been developed, which improves passive design solutions.

Impact:

- Improved affordability and accessibility of advanced building materials.
- Greater flexibility in designing energy-efficient and sustainable structures.

Integration with Renewable Energy Sources:

The integration of renewable energy sources, such as solar and wind power, with passive design principles opens up the possibility of developing comprehensive and durable net-zero structures. (Abdellah, 2019) Technological developments in renewable energy present fresh opportunities to improve the energy efficiency of passive designs.

Impact:

- Increased efficiency in achieving net-zero goals.
- Synergetic solutions that combine passive design with active renewable energy systems.

Conclusion and future architectural practices

Passive design techniques have shown to be very successful in the quest for net-zero energy buildings. They provide a sustainable method that maximizes natural ventilation, heating, and cooling systems. A wide range of tactics, including insulation, thermal mass, daylighting, natural ventilation, and careful orientation, all work together to reduce energy use and achieve net-zero energy targets. These passive measures are important because they improve occupant comfort, encourage resource conservation, and lessen the environmental effect of buildings, all of which go hand in hand with energy efficiency.

Going forward, the use of passive design techniques has to be given top priority in architectural practices as a basic element of sustainable building design. To overcome technological constraints and improve the overall efficacy of passive techniques, practical solutions include the integration of cutting-edge building materials, such as high-performance glass and insulation. Architects should also make use of the potential that renewable energy sources bring, combining them with passive design components to build cohesive and robust solutions. Cooperation between architects, engineers, and legislators is essential to create and execute building rules that promote passive design principles. It is also important that further research and development efforts concentrate on improving the affordability and accessibility of passive design solutions so that sustainable building becomes the norm rather than the exception.

CONFLICTS OF INTEREST

No conflicts of interest was declared by the authors.

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Window Design for Daylight in Buildings

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Abstract— Designing windows to admit natural light in buildings plays a central role in promoting occupant health, energy efficiency and sustainable architectural practices. Natural light through thoughtful window design not only reduces the need for artificial lighting but also helps create healthier and more comfortable indoor environments. Day lighting design goes beyond figuring out how to provide an inhabited room enough light. Effective window design requires a strategic balance between maximizing daylight and minimizing heat absorption or unwanted glare. It consider factors such as window orientation, size, shape and choice of glass material to optimize the distribution of daylight in interior spaces. It consider that climate impact on the building while absorbing daylight through the various window factors preventing by the help of various window design techniques. The aim of this research is to quantify the natural day lighting into building through the various window designs and shape. This research represents the phenomenon of day lighting in buildings. It shows the understanding of energy load in the building which is support by the various formats of the windows formats, their size and orientation of the building. This research simply represents the building simulation for integrated day lighting by Revit 2018 tool and standards. This tool is capable of importing the visual comfort and properties from different glazing, sizes and their shading position from the Window Information System (WIS) Program. This methodology is used to derive the different daylight for different sky conditions. Its implement the daylight calculation which allows the shades through the window recess and overhang. The conclusion of this research is contrasted with the analysis of the window design and daylight for different locations and various orientation of the building which shows the heat absorption in the building. It shows the window design strikes the right balance between the aesthetic, functionality and the sustainability aspect of the building.

Keywords: Window Information System, Day lighting, Building Performance, Simulation, Window Design.

INTRODUCTION

Window is a necessary exposure for the overall presentation of a building. The highly performable building turns into a poor energy performance due to inappropriate building design (Arntsen & Hrynyszyn, 2021). A window or other opening to the exterior that lets in all the necessary natural light, ventilation, or both for a room's interior but isn't a door. (Maria, 2016). In building façade, there are many significance part from a basic terms of window where fresh air, View and day lighting is including. (Rewatkar & Rewatkar, 2016). “Day lighting is the controlled admission of natural light, direct sunlight and diffused sunlight skylight into a building to reduce electric Lighting and saving energy” (Chawla, 2017) (Ander & FAIA, Daylighting, 2016).

Day lighting system in buildings it’s not containing just a day lighting openings which is windows as well as skylights but it's also combined including daylight responsive lighting control system. “Lighting system is majorly answerable for consuming divide sum of energy in buildings all around the buildings. The lighting system could be optimized through the utilization of the control system in building and also through the virtual integration of daylight” (Enedir Ghisi, John A. Tinker, 2005) through the windows (Ghisia & Tinkerb, 2004).

Historical Perspective

It's a hole in the wall that allows light to enter (or an arrow to exit!). “The first “windows” of the bronze and iron ages made up for these shortcomings with wooden shutters, and even by scraping and stretching animal skins (like drum skins) and soaking them in oil. The development of window glass manufacturing techniques led to the production of larger, smoother parts of higher quality. Clarity has played a major role in the design of windows throughout history. The restriction of window size led to the development of lead lights and staggered bars. Early opening windows had side windows and the risk of deformation and lack of hinge precision limited the size of the opening lights. Later windows were vertical sliding sashes because sashes were supported on both sides, allowing them to be opened wide without worrying about warping. Because buildings and windows are usually designed as a whole, they need to be replaced regularly to maintain the overall look. Today's modern windows can mimic these styles, and create many more. Modern windows are generally designed for aesthetic appeal and regulatory compliance, rather than material or process restrictions." (Gregg D. Ander, FAIA, 2016),(Design, 2019).

Evolution of Window

Hollow-core metal window- 1905 Hollow-Core Metal Window Sash Opening: 44" x 100". It's developed in the 1890s, is the hollow core sheet metal window. Both types of windows are manufactured in a variety of configurations, sizes and styles.

1911 Industrial Steel Window- During the early 1900s, the utilization of steel and concrete frame construction became prevalent, by the 1930s, steel windows had become synonymous with the finest aspects of functional industrial design, becoming a staple of Bauhaus-inspired structures. The steel windows of the building are believed to have been produced in England by Henry Hope and Sons. The 4-by-5-foot window displayed is representative of the building, featuring a 20-light configuration and a six-light rotating sash in the center.

1915 Arts And Crafts Residential Window- The window situated at 5803 Waterman Street originates from a building in St. Louis that was erected circa 1915 by contractor Richard Mederacke as a multi-family residence. Its design was tailored to its intended use, with careful consideration given to its size, proportions, and placement within the space.

1920s Residential Window- Throughout the 1800s, machine-made window glass gradually replaced hand-blown glass in both cylinder and sheet forms. As glass manufacturing continued to improve, imperfections were eliminated, leading to the widespread use of one-over-one windows by the end of the century.

1926-1927 (Sliding Windows)- In 1902, Le Corbusier, Dr. Karl Turban, and architect Jacques Gros recognized the necessity for a new type of window in their Sanatoriums for the treatment of tuberculosis. This need was later fulfilled in the form of a large steel-framed glass slider, measuring 4.65 x 3.5m, with a sash composed of two panes of 2.3 x 3.5m glass, which was utilized in the construction of Villa Savoye in Poissy, France from 1928-31.

1930s Residential Casement Window- This wooden casement window, produced during the early 1930s, originated from the Andersen Corporation located in Bayport, Minnesota. The factory meticulously fitted and glazed the sash, while an additional interior storm window panel, which could be easily removed, was offered as an optional feature.

1932 Aluminum Commercial Window- During the 1930s, aluminum windows gained popularity in the market due to their modern appearance and aesthetic appeal. The most commonly used surface treatment between 1920 and 1950 was the "no finish" or "mill finish." In 1932, the Campbell Metal Window Corporation of New York manufactured aluminum double-hung windows for the PSFS Building in Philadelphia, which had over 3000 separate aluminum window units.

1950 Pivoted Windows- This product is offered in either anodized or powder-coated aluminum. It is available with a choice of standard 4mm glass, toughened glass, or laminated safety glass. The dimensions of this product range up to 2.4m in width and 1.8m in height, while the sash sizes can reach up to 900mm x 900mm. (Rohit, 2022).

1980 Clerestory Windows- Even modestly sized windows, such as those measuring 2 feet by 2 feet, have the capacity to allow ample natural light to permeate a space, while their positioning at a certain height helps to minimize the intensity of glare indoors. American architect Frank Lloyd Wright played a pivotal role in incorporating such windows into contemporary residential structures.

Tilt-And-Turn Windows- Timber tilt and turn windows, specifically, are obtainable in a range of dimensions, with a minimum width of 400mm and a maximum width of 1,400mm. Additionally, they possess a minimum height requirement of 500mm, extending up to a maximum height of 2,470mm.The width of these windows can vary from a minimum of 540mm to a maximum of 1,400mm. Similarly, the height of these windows can range from a minimum of 620mm to a maximum of 2,385mm.

Windows Regulate Ventilation

The provision of fresh air within a space is dependent on the location and size of the window, as it allows for the inflow of fresh air. The effectiveness of air ventilation is influenced by various factors such as wind velocity, window size, location, and placement. It is worth noting that a single window positioned on the windward side of a room will be less efficient compared to having two windows. An exemplary illustration of effective ventilation can be observed in the "Energy Research Institute Bangalore Designed by Ar. Sanjay Mohe. The windows in this building are designed to let in plenty of light and air while keeping out the polluted air from the adjacent nallah which is situated on the south side of the building. The windows are designed to allow maximum glare free natural light to enter the building from the north side and a blank wall is included on the south side to create a negative pressure that pulls fresh air in from the north side."(Rewatkar and Rewatkar, 2016).

Daylight in Composite Climate

It shows the characteristics of the hot warm & humid as well cold climate under the composite climate. This climate have intensive solar radiation, temperature, and wind in monsoon, hot & dust in summer (Poptani & Parveen, 2022). "The composite climate has a lot of daylight, mainly due to the high intensity of the sun and the long duration of light in a tropical composite climate. The design sky illumination in this particular climate can reach about 12,000 lux assuming the sky is overcast." (Roshan, 2014). The composite climate has a high amount of daylight, mainly due to the high intensity of the sun and the long duration of its light in the tropics composite climate. (Mohapatra, Kumar , & Mandal , 2018).

Enhancing Productivity

Productivity can be defined by five basic factors: Visual Size, Luminance Contrast, Color Difference, Retinal Image Quality, Retinal and Illumination. These components are typically present:- "Daylight-optimized building footprint, High-performance glazing, Day lighting - optimized fenestration design, Skylights (passive or active), Tubular daylight device, Daylight redirection devices, Solar shading devices, Daylight-responsive electric lighting controls, Daylight-optimized interior design"(Alpana Kamble, 2021).

Design Considerations

Strategic design is needed to maximize natural light harvesting in a structure while reducing the demand for artificial lighting. Reducing floor plate depth from north to south, eliminating east and west exposure, and optimizing south and north-facing facades are all necessary for optimal daylight fenestration. Efficient day lighting also necessitates carefully designed electric lighting circuits. The outside 10-15 feet of the building's perimeter should receive enough daylight to allow for light dimming or switching, resulting in a pleasing blend of artificial and natural lighting (Ander & FAIA, Daylighting, 2016). Floor area must meet or exceed the Useful Daylight Illumination (UDI) area for 90% of possible sunlight hours in a year. The minimum floor percentage requirement of the building shall be 100 lux to 2,000 lux of illumination. For every square meter of floor area, the UDI shall be specified for at least one site. Fenestration shall be modelled using real visual light transmission (VLT) in accordance with the material specification sheet.(Amalia Yunia Rahmawati, 2020). Percentage of above grade floor area meeting the UDI requirement for educational and business building category for ECBC- 40%, ECBC+ 50%, SUPER ECBC-60% (Energy Conservation Building Code, 2021).

NBC:-

Sky Component (SC):-Window is placed at a distance of 3 to 3.75m from the center line which is perpendicular to the window.

The sky IL luminance is recommended for various climates:-

"6800 lux for cold climate, 8000 lux for composite climate, 9000 lux for warm humid, 10500 lux for hot dry climate"(Crystallography, 2016).

$$\text{Fenestration Area} - \frac{\text{Window Area} \times 100}{\text{Floor area}}$$

Window Shape and Position

"The placement of windows must be carefully planned. Windows on opposite walls provide good day lighting but make it hard to avoid screen reflection and glare. Provide the most window space on the side with the most solar exposure to reduce combined mechanical heating and cooling demands. The amount of reflected or absorbed light increases continuously from zero to approximately 45° when the angle of the light beams between the glass and the light source is 90°.(Energy, 1997). Glazing determined Placement and shaping of windows for daylight entry is simply a question of making sure that areas that need high daylight factors 'see' as much of the sky as they can.

High window heads by geometry will allow deep daylight to enter the room. Different window shapes and positions create different daylight distribution within the room."(Wilson, 1999).

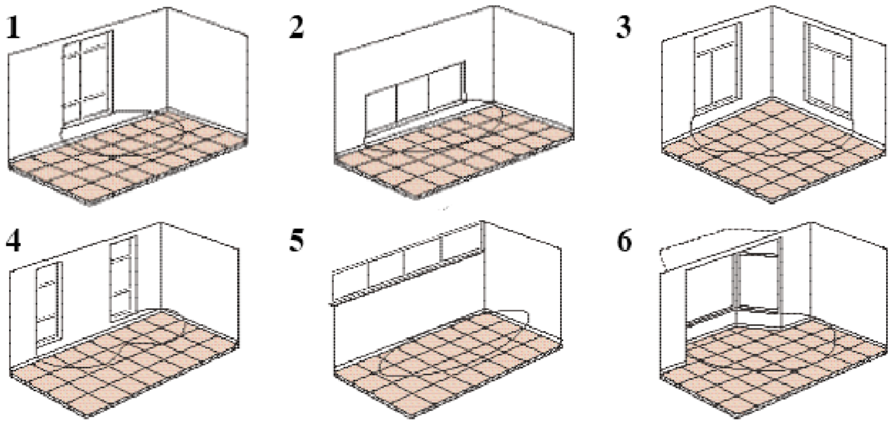

Figure1. Daylight distributions produced by different window positions (source- author)

Reference. (Source- author)

Window 1- it's a small & square. Its only allow some natural light to enter the upper part of the room. But

It's not significant on overall lighting.

Window 2- this is a large & rectangular shape of window, it will allow natural light more than WIN-1, also more effective lighting on lower part.

Window 3- it's a small & square shape window, it's provide some natural light but not a significant impact of lighting.

Window 4- it a long & narrow window, is similar to WIN-1 it will allow the natural light to upper part of the wall.

Window 5- this is a large rectangular located on upper level of wall, it's similar to WIN-2 & it's allow more natural light to the room.

Window 6- there's a tall and long window which is usually known as bay window, it also similar as a WIN-3 it's allow natural light to penetrate deep into the corner of the room, but it may not provide that light to the rest of the space.

Day lighting Technologies

The implementation of a day lighting system will involve the utilization of various technology types and construction methods, including but not limited to:

Exterior Shading and Control Devices.-In regions with high temperatures, exterior shading mechanisms frequently prove effective in mitigating heat gain and diffusing natural light prior to its entry into the working environment. "Light shelves, Overhangs, Horizontal louvers, Vertical louvers, Dynamic tracking of reflecting systems" (Whole Building Design Guide, n.d.).

Glazing Materials.-In order to optimize a fenestration system, it is imperative to comprehend three glass characteristics. Increasing the glazing area is the most straightforward approach to maximize daylight within a space. U-VALUE: Its represents the rate of heat transfer due to temperature difference through a particular glazing materials.

Shading Coefficient:-The comparison between the solar heat gain of a specific glazing assembly and double-strength, single glazing is denoted by a ratio. "It is worth noting that term in which shading coefficient is being gradually replaced by solar heat gain coefficient, which is a related to this term".

Visible Transmittance:-The visible light transmission of a glazing material can be measured to determine its effectiveness. Glazing can be easily altered to improve thermal and optical properties. Manufacturers provide a variety of options, such as tints, metal and low-EMISSIVE coatings, or fritting. U-values can also be improved by using multi-paned glazing with an inert-gas fill (e.g. argon, krypton). For optimal daylight in large buildings in a wide range of weather conditions, "glass with a moderate to low shading coefficient" and high visibility transmittance is recommended".

Aperture Location.-Daylight penetration into a space can be facilitated by employing uncomplicated side lighting strategies, which note Ventilation. Generally, the extent to which daylight permeates a room is approximately two and a half times the vertical distance between the upper edge of a window and its sill.

Reflectance of Room Surfaces- The best way to improve daylight performance is to keep the reflectance of room surfaces high. Ideally, the reflectance of the ceiling should be over 80%, the walls should be 50% or higher, and the floors should be around 20%. Of all the surfaces in the room, the floor has the least impact on daylight penetration. The key to a good day lighting design is to integrate it into the electrical lighting system. Thanks to modern lighting controls, you can now control the electrical light level when you have enough daylight." (Whole Building Design Guide, n.d.). Commercially, there are three types of controls available(Ander D. Greeg, 2016).

Switching Controls: The on-and-off controls function by deactivating the electric lights in the presence of sufficient daylight.

Stepped Controls: Individual lamps within a luminary can be controlled to offer varying degrees of electric lighting, allowing for the provision of intermediate levels of illumination.

Dimming Controls: To further develop the sunlight lighting, you can adjust the power contribution to the lights to control the electric lighting. Integrate any of these control methods with your building management system to take advantage of its built-in control capabilities. To make the most of the daylight available and avoid areas with poor lighting, it's important for your lighting designer to plan the lighting circuits, switching schemes, and fenestration carefully. The control scheme types are illustrated in the accompanying figure.

Other Lighting Control Schemes.

Occupancy Controls: These sensors can detect motion or the surface temperature of objects, "which allows them to automatically turn off or dim lights in dark rooms." Typical energy savings are between 10% and 50% depending on user case." (Whole Building Design Guide, n.d.).

Timers: Timers are cost-effective devices that function as time clocks, specifically programmed to automatically switch off lamps or lighting according to a predetermined schedule. In cases where "spaces are known to be unoccupied during specific time periods, the utilization of timer becomes highly advantageous in reducing energy consumption and minimizing cost"(Ander D. Greeg, 2016)

Slightly Technical Background

Fenestrations have various examples such as windows, skylights, sliding glass doors and glazed doors. Its including any shading devices linked to it, as well as its frame and other opaque parts, controls the amount of solar radiation and daylight that enters the building. It also encompasses the transmission, absorption, and reflection processes of glazing.

Energy Flows

There are two types of energy flows via windows. There should be solar heat gain is priority and later conduct interior heat into exterior in winter and exterior heat inside in building. The solar gain is divided into two components. First, solar radiation that is directly transmitted & second which is absorbed by the glass and opaque parts of the window and subsequently conducted, convicted, and radiated to the interior.

U-factor

The V-factor, a coefficient that reflects the capacity of a window to prevent conduction transfers, characterizes its insulating capabilities. Heat transfer is measured in watts of heat flow per unit area. Per window and degree of temperature distinction between the inner and outside. For windows in cold locations where the temperature is below freezing for much of the time, the delta T's are enormous. Having a low V-factor is critical this year. High solar gain is ideal for such settings. Too may be quite beneficial in warming the When the light shines through the windows on a frigid winter day. "There is a distinction in NFRC ratings between the V-factor of a glazing system's center, the glass's edge (which has a typically a greater V-factor in general), and the frame. There is also a global V-factor for the entire window. Assembly The total V-factor is the most important value. For calculating energy efficiency" (Rose, 1993).

CASE STUDIES

This research aims to contribute to the existing body of knowledge by examine various window design strategies and their impact on daylight performance. This simulation is done by the Autodesk Revit 2023 software. This software find the daylight factor and illuminance LUX level of the building VVIP Circuit House is a Guest House is located in Pune, its angle is North-East. Department of Architecture, DCRUST is located in Murthal, Sonipat. Its angle is North- South.

VVIP Circuit House

Architects: Sunil Patil and Associates, Area: 10540 m^2, Year: 2014

Location:-It's found within the center of the cantonment zone of Pune. This building have two floors in cantonment area. It's situated between 17. 5 and 192 degrees North and 73. 2 and 751 degrees East. Its faces East and West. The houses are in the north and south, where things block the sun but let in fresh air. The courtyard is covered with pergolas that make a partly-shaded open space.

Building Faces:-The south side of the building gets a lot of sun in the winter, which makes it hot and bright. There are some narrow panels with openings are also put in to let in light and keep the building cool from January to November. The east side is only important in the morning. The front face gets the most sun. To keep out the heat, most of the front of the building doesn't have windows and only some extra rooms are planned on this side. This building got a GRIHA five-star rating. This project is planned to use passive strategies for things like windows, layout, and zoning. The courtyard and the areas around it are shielded from the sun but still get a lot of fresh air (ARCHITECT, 2018).

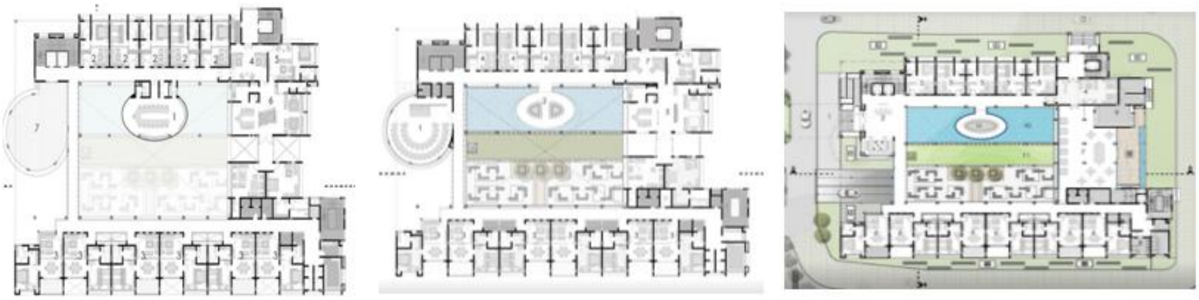

Figure 2. Ground, First & Second Floor Plan (Arch Daily, n.d.)

Reference. (Source- Arch daily)

Simulation Result

Examination of this building's information is collected from computer program which provide the LUX information. Their result of investigation is done through simulation program Revit 2023 is based on window introduction in building. (Source; - Autodesk Revit 2023).

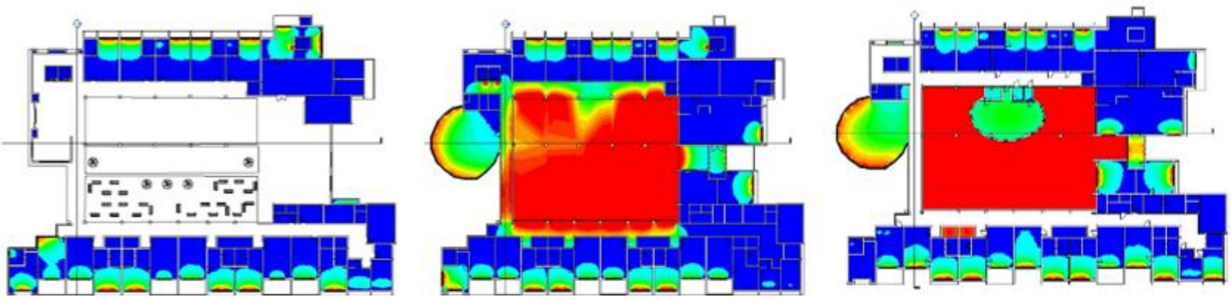

Figure 3. Ground, First & Second Floor Plan (source-Revit 2023)

Reference. (Source- Autodesk Revit 2024)

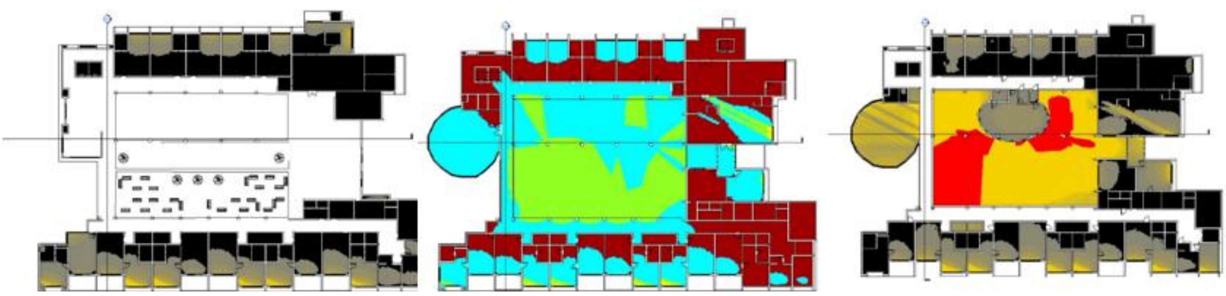

Figure 4. IL luminance level 1, 2 & 3 (source- Revit 2023)

Reference. (Source- Autodesk Revit 2024)

Figure 3- shows the approachment of light less than the other floors of the building. There scale reach out to the 3m of the room. Its passing is 15%. Its shows the daylight in the room which is expanded up to 3.32m there varies up to (0-5305). There daylight reach almost of the area on this floor. Its passing is

36%. Daylight is reaching to their spaces the daylight factor of 0-88. Its day passing is 21%.

Figure 4- shown the variation of lux on the different floors, theirs black portion is described the non approachment portion of the building of the light.

Department Of Architecture, DCRUST, Murthal, Sonepat

Total area of block- 6081 sq.mt.

Ground, First & Second Floor- 2027 sq.mt. Each floor

The location is found Murthal, on National Highway no.44, 50 km from the ISBT (Delhi) 2.4 km from Sonipat bus stand. It situated 29°1’38”N77°3’44”E (Wikipedia, 2023).

Orientation:-The building faces North and South. The classrooms are in the north and faculty rooms are in the south facing, where things block the sun but let in fresh air.

Building Faces: -The building's south side is sunny in the winter and gets very hot and bright. The southern side of the building is very important, but there are also some small panels with openings to let in light and keep the building cool from January to November. It allows the daylight in the building but stopping the glare.

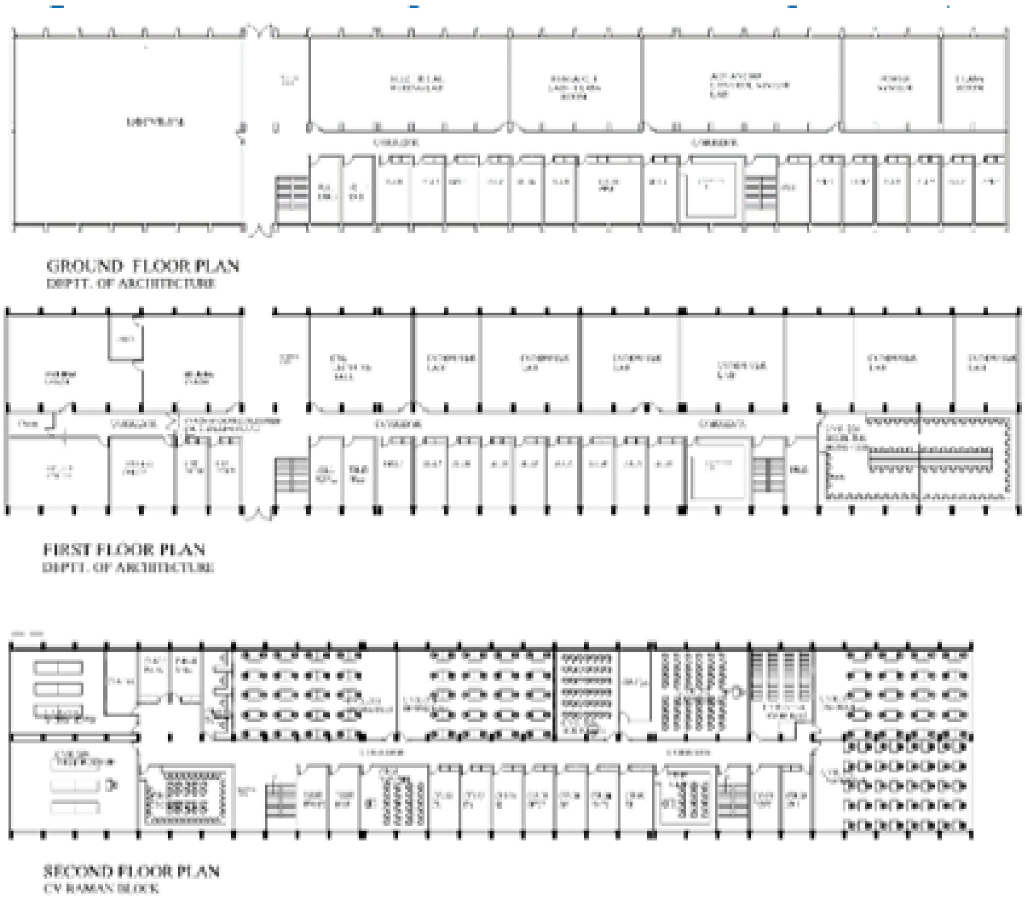

Figure 5. Electrical, Computer & Architecture Department (source - AutoCAD Reference. (Source- Autodesk AutoCAD 2024)

Simulation Result

These models investigation in software Revit 2023 with Brilliance plug in program. The result of sunshine investigation from the taking after is choose based on window in building. (Source; - Autodesk Revit 2023).

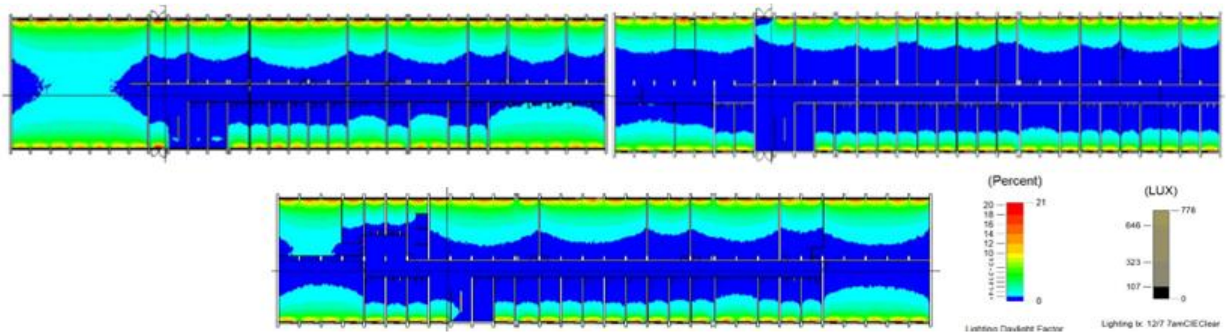

Figure 6: Electrical, Computer & Architecture Department (source -Autodesk Revit) Reference. (Source- Autodesk Revit 2024)

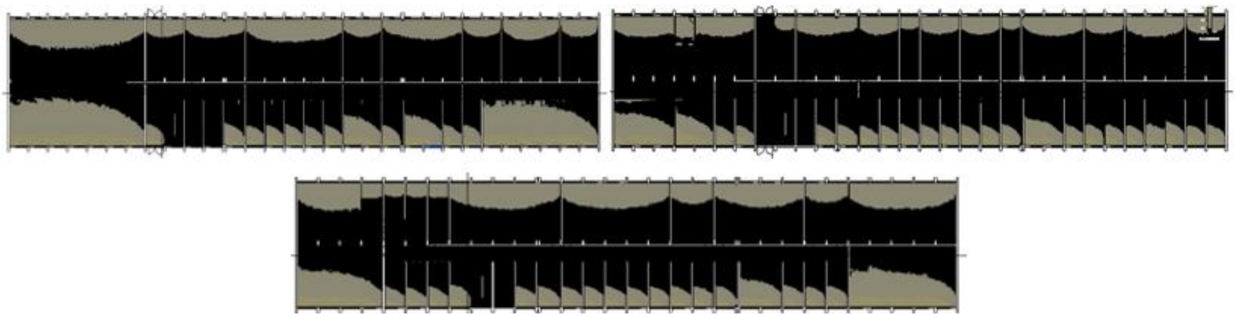

Figure 7: Illuminance level 1, 2 & 3 (source -Autodesk Revit) Reference. (Source- Autodesk Revit 2024)

Figure 6- shows the daylight more than the other floors of the building. There scale reach out to the 4m of the room. Its passing is 25%. Shows the daylight in the room which is expanded up to 3.32m there varies up to (0-778). There daylight reach almost of the area on this floor. Its passing is 36%.

Figure 7- daylight is reaching to their spaces the daylight factor of 0-88. Its day passing is 21%. Shown the variation of lux on the different floors, theirs black portion is described the non approachment portion of the building of the light.

Comparative Analysis:-

Types	ECBC	VVIP Circuit House	Department Of Architecture, DCRUST, Murthal, Sonipat
LUX	Min. 100 & 2000	3572-3900	323-600
DF	Educational ;40-60% Guest House-30-50%	20-88	16-18
Window	40%	2000X1500	900X1200
Glazing	-	Single	Single
Performance	-	Good	Good

Figure 8. Comparative analysis of these studies.

CONCLUSION

As earlier state, window daylight plays an important role in improving students' performance. Therefore, larger openings are shown in the north and south introduction and smaller openings in the east and west introduction. Due to the warmth and glare of the openings within south veneers, flat shading devices are most suitable. Shading devices are used in the north and south exterior to reduce the warm pickup and glare and allow the winter sun light into the interior. To acknowledge the limits, this research gone through simulation were carried out in composite climate to analyze daylight in the building. In (CASE 1- with a range of 5305 to 0 lux & daylight is 0-88% Suggestions like adding skylights, using dark tinted windows & CASE-2 with a range of 778 to 0 lux &daylight factor varies from 0-21 %. All of the preceding study reviews reveal that there are numerous of windows affects the daylight in the room by their sizes and mostly on the orientation. It also reveals that the design of the building. It's expected, there should have a comparison of subjective and objective measurements to yield more user friendly results'.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Geodesign Based Approach for Flood Resilient Town: A Case Study of Kullu, Himachal Pradesh

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Abstract— Flooding is a natural disaster characterized by the inundation of land areas due to the overflow of water from its usual channels. In recent years, Kullu district of Himachal Pradesh has experienced number of devastating floods due to its proximity to the Beas River and the Himalayan terrain which caused collective damage to man made as well as natural resources, often lead to loss of lives. Recognizing the urgent need for flood resilience, the present study aims to develop a flood resilient town through geodesign framework which will reduce the impact of floods in hilly areas. The study utilizes a three-stage geodesign framework which involves data collection, data analysis and geodesign-based flood resilient modelling. In the first stage, collection of historical flood data and geospatial data of the study area was done to identify vulnerable communities and assess critical infrastructure at risk. In the second stage, flood susceptibility mapping was done based on the analytical hierarchy process (AHP) which allows decision-makers to consider and weigh multiple criteria such as elevation, topographic wetness index, slope, LULC, precipitation, and drainage density etc. and assigning relative importance to each criterion, AHP provides a structured and transparent process for assessing flood susceptibility. In the third stage, interactive three-dimensional (3D) modelling was done in ESRI CityEngine to develop a flood resilient model for the study area which integrates geospatial data, flood simulation, land-use planning, and community engagement. The results show that by focusing on flood resilience, this model offers a valuable insight and practical approach to shaping the development in hilly areas that can withstand and adapt to the challenges of increasing flood occurrences while minimizing their impact on human lives and property.

Keywords: CityEngine, Floods, Flood Resilient Town, GIS, Hilly Regions.

INTRODUCTION

The most frequent and extensive kind of natural disaster in the Indian Himalayan Region (IHR) is severe flooding (Gardner, 2002). The ecological system of the Indian Himalayan region is intrinsically illusive and is composed of several mountain ecosystems that are prone to geological instabilities and natural disasters (Geneletti and Dawa 2009; Prasad et al. 2016; Ruiz-Villanueva et al. 2017).The state of Himachal Pradesh (HP), which is situated in the northwest Himalayas, is exposed to roughly 25 different kinds of hazards and disasters of diverse magnitudes, including cloud bursts, landslides, and flash floods (Rawat, P., 2013; Ruiz-Villanueva et al. (2017); Sah, M. P. & Mazari, R. K., 2007). Seasonal hydro-meteorological conditions in the state of Himachal lead to frequent occurrence of water-induced flash floods (Nibanupudi et al., 2015; Paul et al., 2000; Sah, M.P., Bist, K.S., 1998; Sah, M. P., &

Mazari, R. K., 1998; Sah, M.P., Virdi, N.S., Bhartarya, S.K., 1996; Sharma, D. D., & Lecturer, S. n.d.). Flash floods are typically brought on by torrential downpours over a short period in a smaller region, which causes the river to overflow embankments, landslides, and mudflows (Hapuarachchi et al. 2011). It occurs mainly in streams and small catchments that covering an area of roughly 100 sq. km (Kelsh, 2001).

In recent years, population growth and expansion of human activities have significantly increased the impact of natural disasters in the Himalayan region and it also experiencing a rise in cloudburst-induced floods within the past two decades (Kahlon, S., 2014; Singh, S., & Lal Kansal M., 2022). In comparison to 2020, cloudbursts during the monsoon season in HP increased by 121% in 2023. As the area is mostly threatened by floods, it is crucial to build adaption plans based on sustainable development and resilience. Geodesign has been considered an essential approach for accomplishing this kind of development since resilient planning demands that several complex issues be taken into consideration (Kulawiak et al., 2014; Musa et al., 2016). The increasing demand of geodesign for long-term planning and the need for people to adapt to and lessen the effects of future natural disasters (Abid et al., 2016; Carlson et al., 2016; Muis et al., 2015). The present study examines the creation and application of a geodesign framework intended to improve flood resistance in a case study region.

LITERATURE REVIEW

The analysis of flash floods in Himachal Pradesh, India, is critical due to its destructive impact on the region's economic and ecological fabric. Various researchers carried out research on a variety of issues, which include the climatic change causes, hydrological events, and vulnerability assessments related to regional flash floods (Kumar et al., 2018; Rathore et al., 2020). This research gave significant insight into the complex nature of flash floods in Himachal Pradesh. But there remains a significant gap in the research addressing the long-term efficiency as well as sustainability of mitigation strategies carried out to reduce the impact of floods. A comparative study of existing research publications on floods and flash floods in Himachal Pradesh reveals a lack of studies that emphasize community resilience strategies in hilly regions, indicating a large gap in the literature. The current study intends to fill this gap by developing strategies and guidelines for flood resilient town through geodesign framework to reduce the impact of flood in hilly region.

MATERIAL AND METHODS

Study area

The study area is located in the Kullu district in the northwestern Indian state of Himachal Pradesh as shown in Fig.1. Situated along the north-south valley of the Beas River, covering an area of 5500 sq. km. Kullu, Manali, and Bhuntar are major urban towns as well as popular tourist destinations situated along the wide, extremely fertile floodplains of the U-shaped valley. The Parvati, Tirthan, and Sainj are three significant tributary rivers that are characterized by small side valleys with villages placed on steep slopes or on the limited, often flat, areas that are prone to flooding.

Methodology

Research involves the collection, analysis, and evaluation of a city's present situation and development of design and strategies based on resilient planning. Because developing resilient and sustainable cities requires considering several difficult issues (Gerges, F., 2022; Kulawiak et al., 2014). Geodesign is a vital approach for accomplishing these advancements. A three-stage conceptual Geodesign framework for flood-resilient communities is shown in Fig. 2.

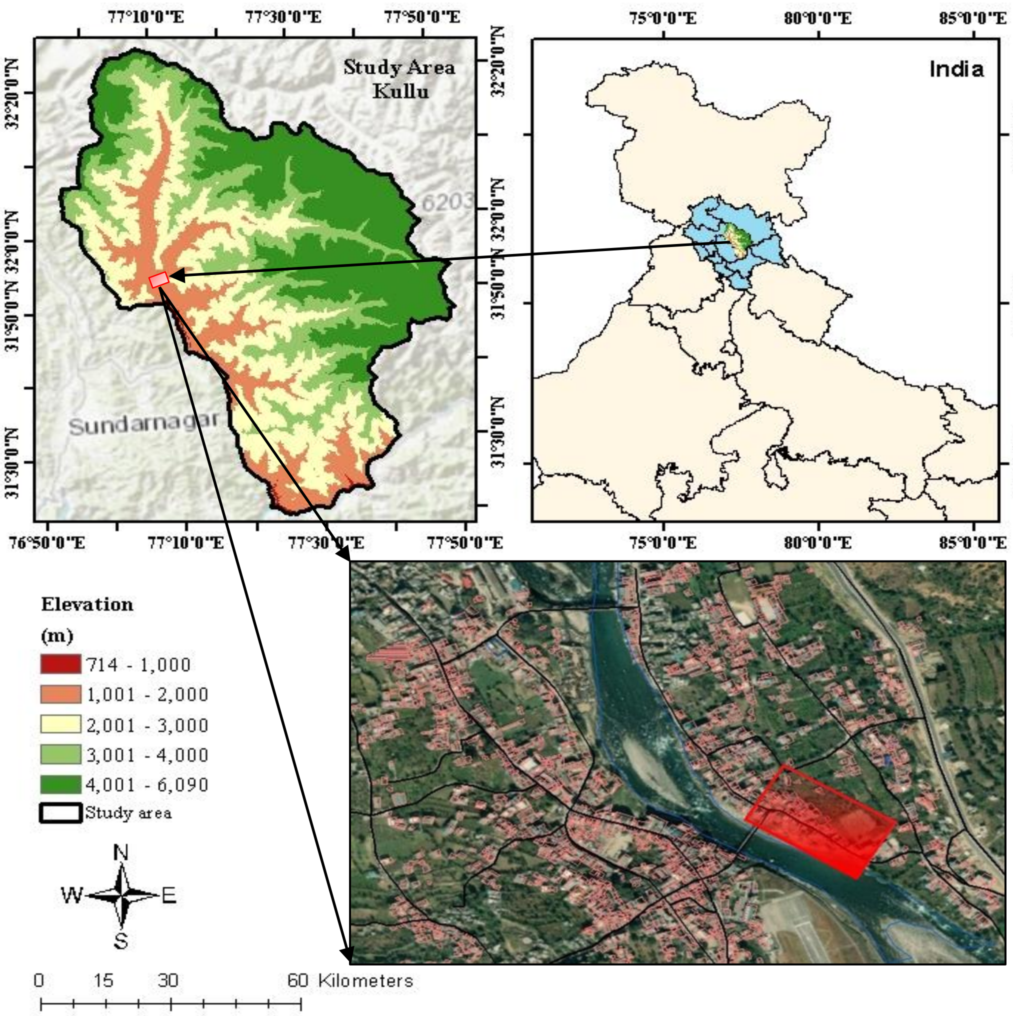


Figure. 1: Study site located in Kullu district, Himachal Pradesh.

Data collection

The first stage was based on collecting geographical and historic flood data for the study area. Ten essential variables were recognized, comprising TWI, elevation, slope, drainage density, road and river distance, precipitation, LULC, NDVI, and geomorphology. ArcGIS was used to create and evaluate the thematic map layer that corresponded to each crucial element.

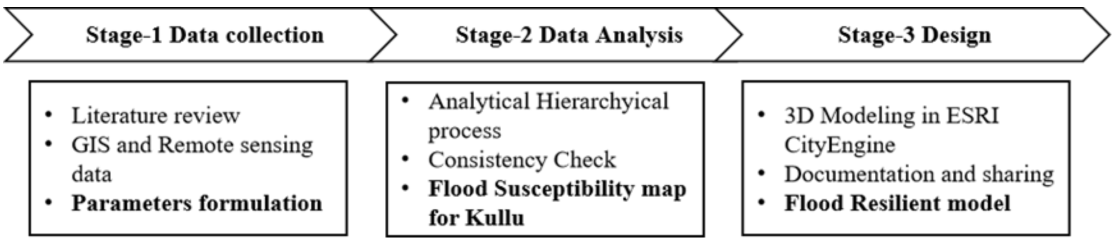


Figure. 2: Three stage geodesign framework for the study.

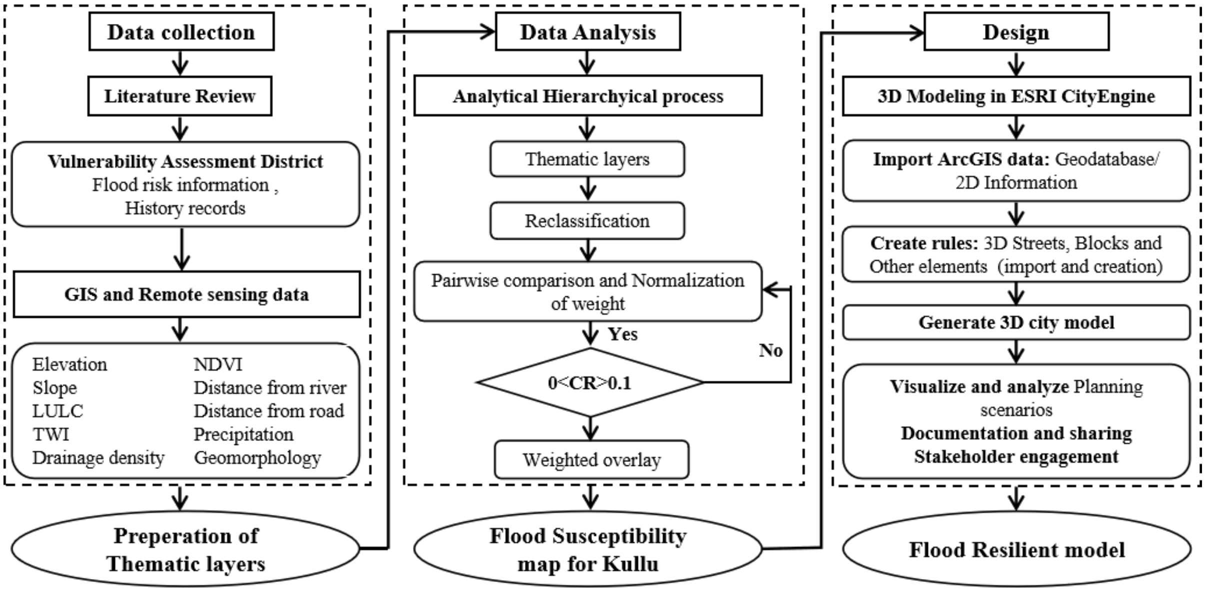


Figure.3: Methodology adopted to generate Flood resilient model.

Data analysis

The data collected in Stage 1 was spatially analyzed to develop the flood susceptibility map. The comprehensive process for creating the map that is vulnerable to flooding is shown in Fig. 3. The Analytical Hierarchy Process (AHP) was implemented to weight essential factors and identify flood-prone locations in study area using expert pairwise comparisons. In this study, a scale value ranging from 1 to 9 was allocated in the decision matrix to determine the potential of every factor connected to flood vulnerability. The normalized weight (W) was calculated by comparing each factor pairwise. A consistency ratio (CR), whose value must be less than 0.1, was calculated to assess the coherence of the expert opinion. A CR of more than 0.10 indicates an unsatisfactory level of consistency (Ghorbanzadeh et al, 2020; Alaneme et al, 2021).

The value of CR was calculated using equation (i). where CI is the consistency index and RI is the random index.

CR = CI/RI………………..(i)

The following formula is used to calculate CI, where n is the number of components and λ_{max} is the maximum eigenvalue of the matrix.

CI = $(\lambda_{max} - n)/(n - 1)$ ………………..(ii)

Flood resilient modeling

ESRI City Engine 2019.0 was utilized to create a 3D model by generating multiple scenarios, which offers multiple design options inside a setting. Gather pertinent spatial data, such as elevation, land use, and hydrological information etc. by using GIS and then these maps into City Engine. City Engine's rule-based modeling features were used to produce 3D urban designs that are adaptable and flood resilient. It involves utilizing GIS's 3D visualization to facilitate interactive dialogues between the public, stakeholders, and decision-makers. Moreover, CityEngine scenes can be immediately posted online for project model sharing and decision-makers' assessment of research results or design ideas (Neuenschwander et al., 2014; Kim, K. H., & Wilson, J. P., 2015; Vaz, E., 2016; Li, Y., & Kim, Y., 2022).

Results and discussions

ArcGIS was used to create thematic layers which shows that the TWI value was found to vary between 1.4 and 26, which is compatible with the high range of areas that are vulnerable to flood. In the study area, six LULC classifications were identified: permanent snow, waterbodies, built-up areas, barren terrain, agricultural land, and forests. Permanent snow areas and waterbodies are positively correlated with flood vulnerability. The drainage density value varies between 0.02 to 1.65 km^{-1} and the precipitation value ranges from 683 to 1930 mm, which shows that locations with higher numbers indicate a higher risk of flooding. The distance from the rivers is another significant factor that affects the risk of flooding. The flood vulnerability was shown to be strongly correlated in the areas where the river distance is less than 500 meters away. The study area's ranges from 714 to 6092 meters and slope ranges from 0 ° to 83.1 ° as shown in Fig. 4 a, b.

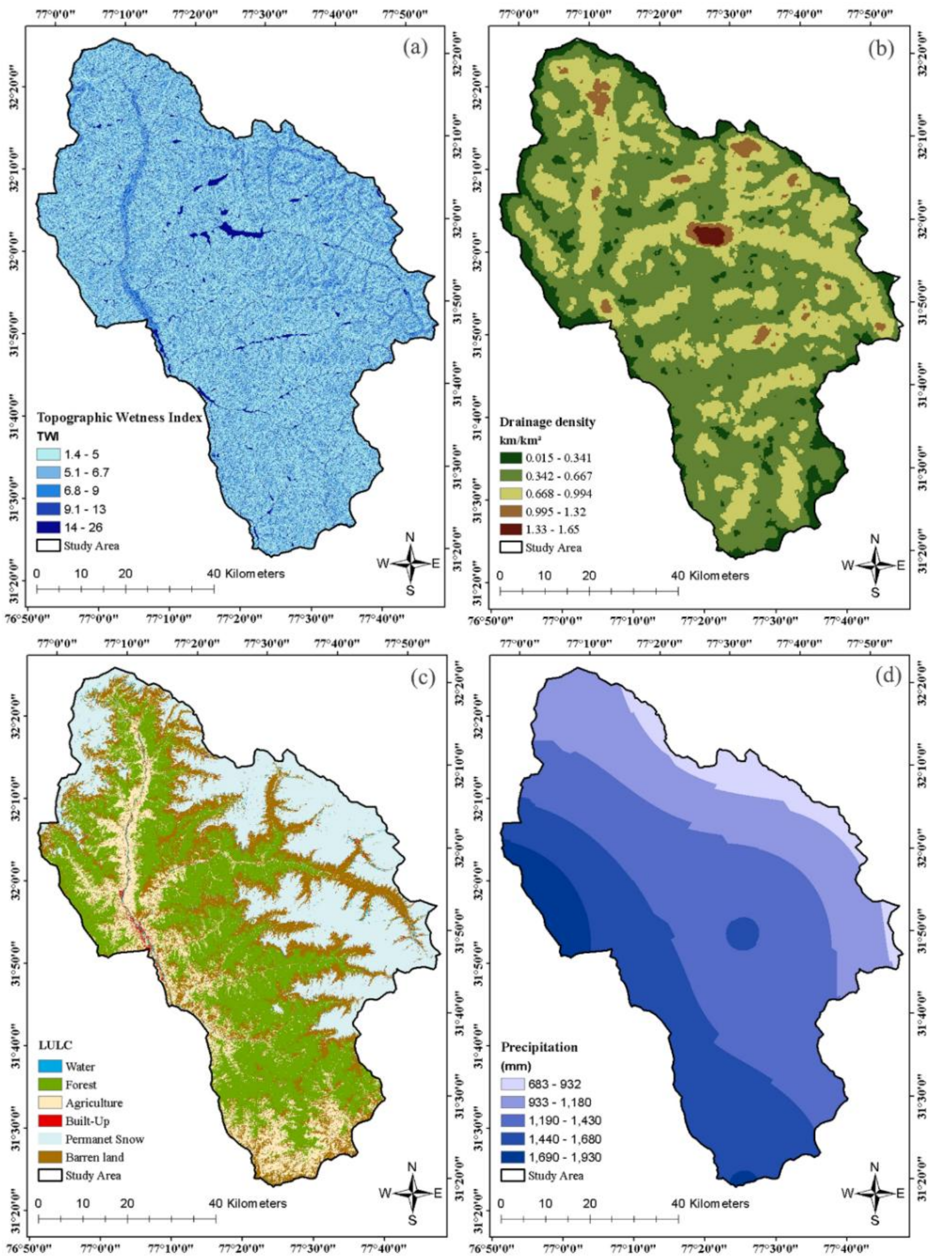


Figure 4: (a) Layers that correspond to the flood-affecting factors: (a) TWI, (b drainage density, (c) LULC, (d) precipitation.

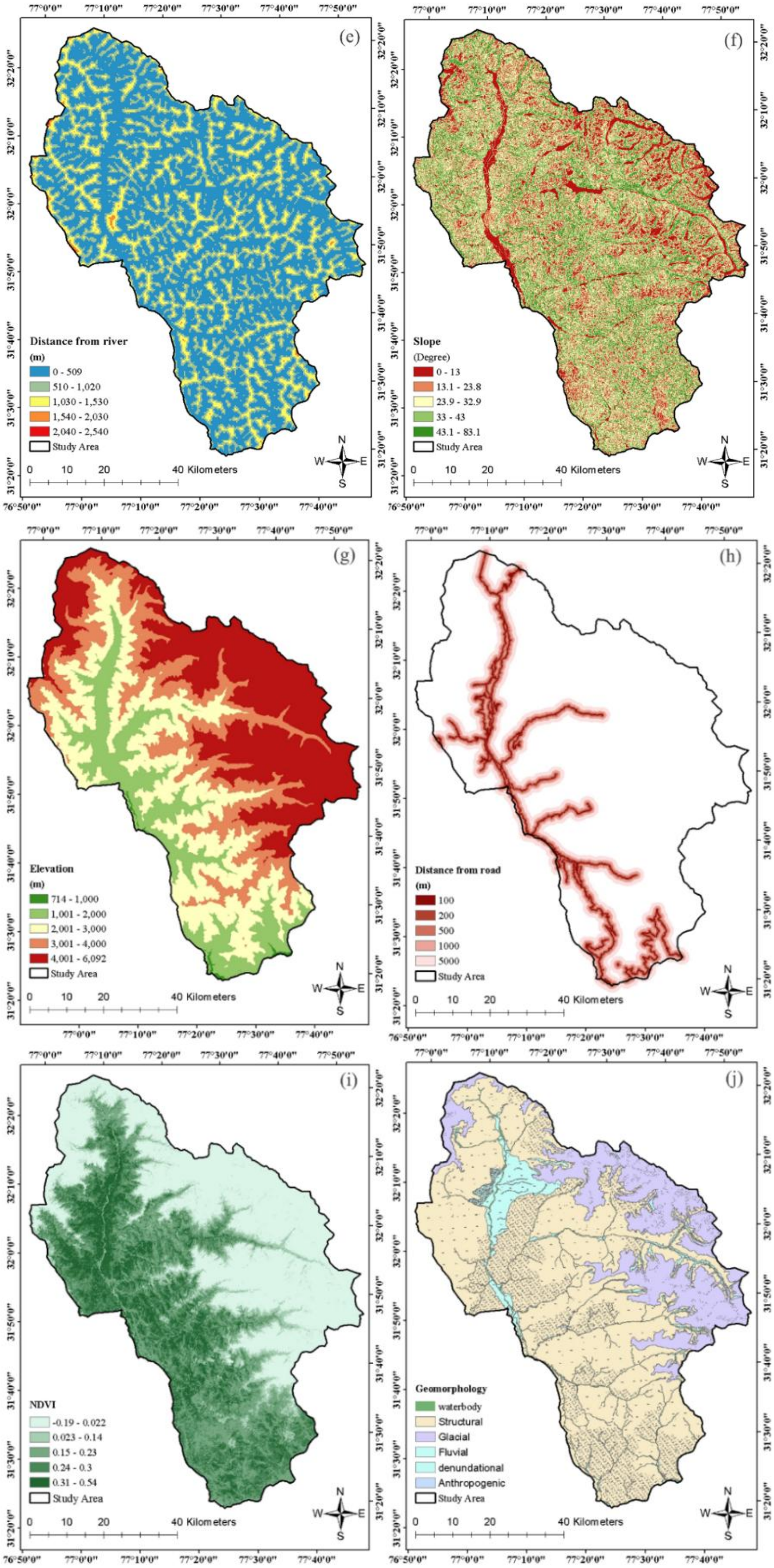
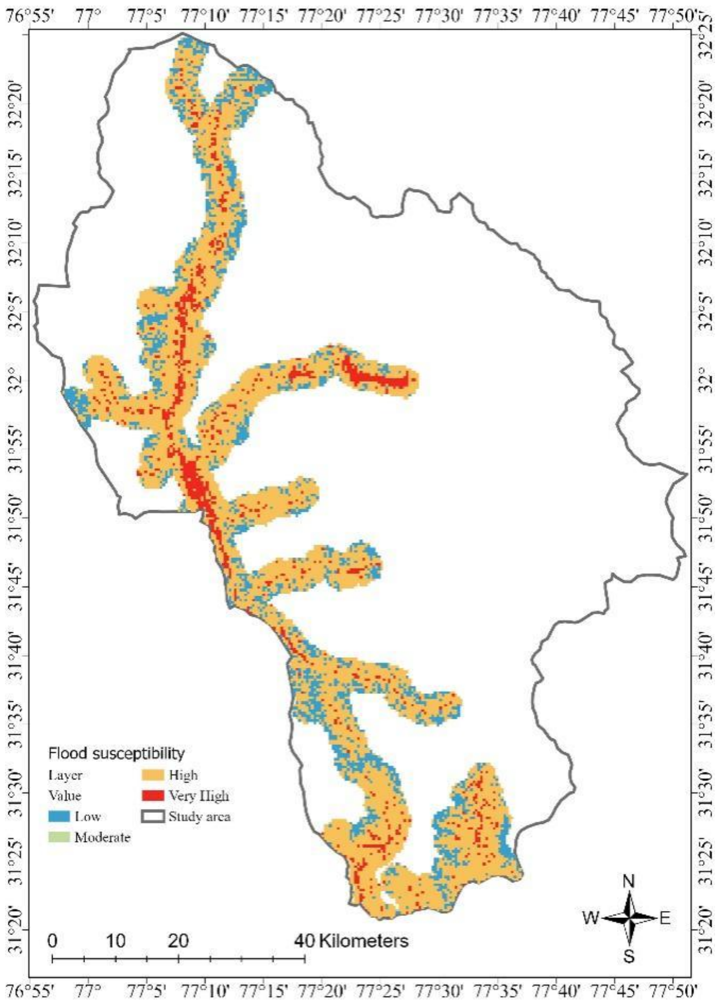


Figure. 4: (b) Layers that correspond to the flood-affecting factors: (g)elevation, (h)distance from road, (i)NDVI, (j)Geomorphology (e)Distance from river (f)slope

Using AHP, the expert opinion analysis shows that TWI, drainage density, LULC, precipitation, distance from river, slope, elevation, distance from road, NDVI, and geomorphology have a weight of 21%, 14%, 13%, 12%, 11%, 9%, 8%, 4%, 4%, 4% and 4% as shown in Table 1. The weights of the grid data were entered and divided into five classes using weighted overlay analysis, resulting in the flood susceptibility map of the research region that is depicted in Fig. 5.

Table 1: Flood affecting factor weightage based on expert survey.

Sr. no	Flood affecting factor	Weights (%)	Rank
1	Topographic Wetness Index (TWI)	21	1
2	Drainage density	13	2
3	LULC	12	3
4	Precipitation	11	4
5	Distance from river	9	5
6	Slope	8	6
7	Elevation	4	7
8	Distance from road	4	8
9	NDVI	4	9
10	Geomorphology	4	10



Geo-design based modeling

Multi-scale understanding of the problems is made easier using 3D visualization when designing settlements that can withstand flooding (Liu et al (2012), Luo et al (2017)). For conducting flood-resilient modeling, the most vulnerable region was considered as shown in Fig. 6 (a). The 3D model of the chosen area was created using CityEngine. This model was created with the adaptation measures in mind, which included adding more green belts, gardens, recreational areas and using permeable paths. The stakeholders deliberated and employed the CityEngine modeling tools to explore potential flood-resilient interventions, as seen in Fig 6 (b). The created model also aids in the formulation of flexible and responsive laws by policymakers to lessen the effects of floods on property and people.

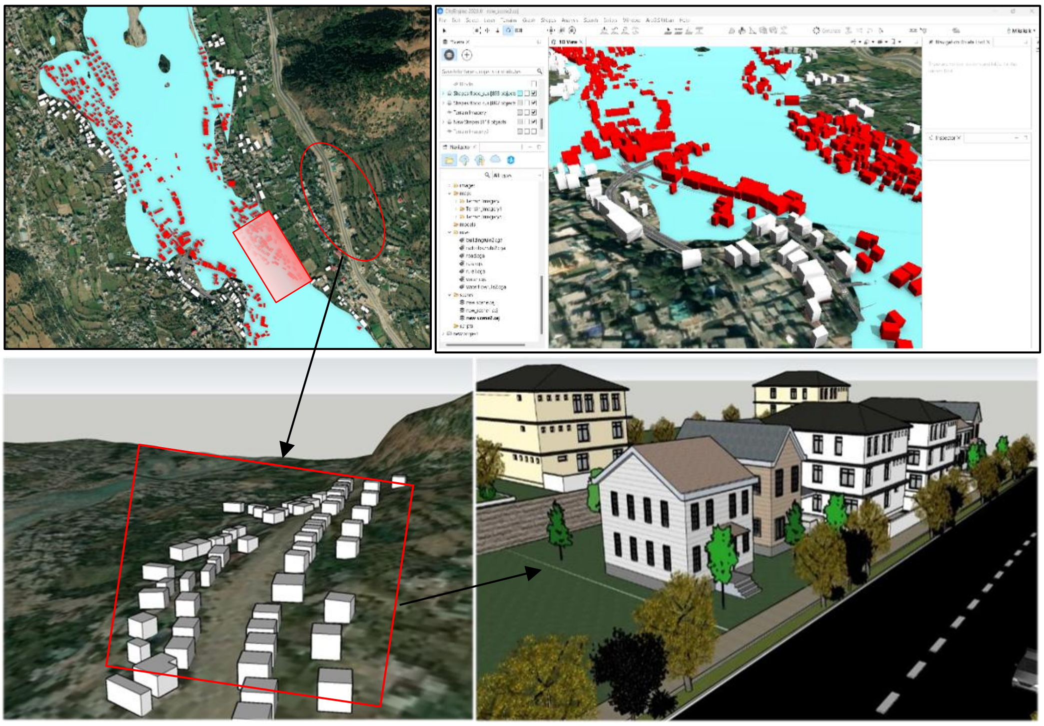


Figure 5 : (a) CityEngine used to identify an area which is mostly

CONCLUSION

The goal of this research was to create a community that is resilient to flooding by using a geodesign-based framework that may reduce the effects of flooding in hilly regions. People can understand and manage the complex procedures of data collection, data analysis, and modelling for flood-resilient planning. The three stages of the framework were used to evaluate whether the design and planning had appropriately considered the factors that influence flooding and to analyse the gap towards flood-resilient planning. For flood-resistant planning, the platform enables the integration of data from various sources and feedback from a range of stakeholders and specialists. It has been noted that the geodesign-based framework allows for the development of more accurate planning and design strategies for hilly locations. Urban redevelopment and flood resilience thinking are needed to facilitate public-government collaboration in planning by utilizing such a platform for engagement, and exchange of ideas.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Jaali: Prominent Feature of Traditional Architecture

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Abstract— Traditional design has become popular for its straightforward answers to severe climatic and environmental issues. As we accept new materials and methods, the quest of thermal and optical comfort has gotten increasingly difficult. Traditionally, jaalis have been used in buildings to give thermal comfort, seclusion, shade, and to control daylighting and air penetration. Despite the growing interest in incorporating these vernacular tactics into modern structures, few studies have examined the relationship between different screen geometries, perforation percentages, shape, and materials, as well as their effects on indoor environmental quality from both aesthetic and thermal perspectives. Case studies from India's hot dry temperature and warm humid environment are used to conduct a comparative evaluation of the Jaali's performance. This research discusses the combined influence of daylighting and air penetration on the thermal performance of a structure in terms of perforation % and size. This study provides a complete grasp of the Jaali characteristics, which are an important aspect in a building's thermal comfort, and serves as a starting point for further research into pattern designs in terms of daylighting and air penetration. The findings motivate architects and engineers to create a framework for maximizing the use of Jaali perforations in line with the building design..

Keywords: Jaali, Perforated screens, Daylighting, Air penetration, Thermal performance, Passive cooling, Natural ventilation, Perforation percentage, Perforation size, Sustainable architecture.

INTRODUCTION

Although jaali (from the Sanskrit words "Jala" and "Jalaka") has been mentioned in ancient Indian architectural writings, the Mughals are responsible for its growth and development, giving it its amazing grandeur and stature. Jaali is an example of Indian stone art from the 16th and 17th centuries. It is a fundamental component in Mughal design. On the borders of platforms, causeways, and terraces of Mughal structures, redsandstone and white marble jaalis were invariably employed. Jaalis are also exquisitely used to cover window and door holes for effect and purdah (veil). They allow in unrestricted air while reducing sunlight's intensity and glare.

Jaalis are utilized as effective ventilators in lavatories, on drains, and in private interiorspaces. The Mughals transformed it from a simple architectural element into a piece of art.

Traditional jaali screens are window coverings seen in Middle Eastern and South Asian architecture. In the past, screen coverings have been effective at giving building occupants shade and seclusion in hot, dry conditions. Jaali screens or other screens have started to be used as ornamental façade components in modern building designs due to interest in traditional architectural aspects.

This study assesses the aesthetic, climatic, historical, and vernacular features of the jaalis that the Mughals brought to India. This dissertation will also include a few real-world case studies to demonstrate how openings (Jaalis) have improved a building's light and ventilation as well as its cultural, artistic, and historic significance. Jaalis are valued for their ability to provide shade and ventilation while maintaining privacy. Their intricate patterns allow air and light to filter through, creating a play of light and shadow in interior spaces. This is particularly important in regions with hot climates, where jaalis help cool and illuminate buildings naturally.

The paper progresses with a specific focus on following

Objectives to achieve the hypothesis:

- To analyse the innovative experimentation in concrete,addressing the processes of form development
- To study the Origin of Jaali.
- To understand Historical and Cultural significance of Jaali.
- To analyze the different climatic factors that affect the design and making of Jaali.
- To identify different pattern and material that affect the design of Jaali.
- To demonstrate the application of Jaali.

This paper examines one such passive design method, Jaali, which has been used in traditional Indian buildings, as well as its possibilities in modern design. Various aspects of thermal comfort can be achieved by adjusting the various parameters of a Jaali. Although there have been individual investigations on the influence of Jaali on thermal and visual comfort, the influence of Jaali patterns, perforation size, and percentage on thermal comfort has yet to be completely investigated. The impact of external traditional perforated screens - Jaalis, which are often used in the Middle East and Southeast Asia, on building thermal comfort in two climate contexts – hot dry and warm humid is investigated in this study. Screen geometries, perforation size, perforation percentages, thicknesses, orientations, and climate zone variances are among the variables investigated.

LITERATURE REVIEW

Jaali as perforated screens for permitting light and ventilation in buildings have been used extensively in India. History has seen tremendous change in the way lattice screens have been conceived across the globe. The study examines and explores the design of Jaalis over time and its varying attributes according to the geography, religion, and a multitude of factors to its modern interpretations and adaptations by contemporary architects through literature reviews and case studies, in the design of sustainable buildings, in India.

Jaalis have a rich and multifaceted historic and cultural significance, serving both functional and aesthetic purposes in architecture while embodying the skills and traditions of the regions in which they are prevalent. They are a testament to the enduring influence of traditional craftsmanship and cultural symbolism in the built environment.

HISTORIC AND CULTURAL SIGNIFICANCE

Jaalis have a rich and multifaceted historic and cultural significance, serving both functional and aesthetic purposes in architecture while embodying the skills and traditions of the regions in which they are prevalent. They are a testament to the enduring influence of traditional craftsmanship and cultural symbolism in the built environment.

- Jaali, also known as "jali" or "jaal," refers to a perforated screen or latticed window typically made of stone, wood, or metal. These intricate designs have significant historic and cultural importance in various regions, including South Asia and the Middle East. Here are some aspects of their significance:
- Architectural Function: Jaalis were primarily used in architecture to serve functional purposes. They allowed for ventilation and natural light to enter buildings while providing privacy and protection from the elements. They are commonly found in the design of windows, screens, and walls.
- Aesthetic Beauty: Jaalis are known for their intricate and artistic patterns. The designs can range from geometric shapes and floral motifs to abstract patterns. These screens add a decorative element to buildings and spaces, enhancing their aesthetic appeal.
- Cultural Symbolism: Jaalis often incorporate cultural and religious symbolism. In Islamic architecture, for example, you can find geometric patterns and calligraphy in the designs, reflecting the Islamic artistic tradition. In Hindu architecture, jaalis are often used in temples and palaces, featuring motifs related to Hindu mythology and culture.

General introduction to jaali around the world

The word “jaali" refers to a net or fine web. It is a decorative perforated screen that may be seen in Islamic, Indo-Islamic, and Indian architecture. It functions as an eggcrate, a tiny size combination of a horizontal and vertical shade mechanism. Although it appears to be two dimensional, the thickness and the connected balusters create several little devices that are comparable to a substantial overhang or a vertical fin.

The jaali has many more uses than a typical window opening, including lattice, honeycomb walling, punctured. stone and timber screens and walls. India's minds have created the jaali from the dawn of recorded art to filter the glare and harsh sunshine into pleasant, breeze-filled spaces. This technology is really an Indian invention because India has utilized it the most of any other nation. 30 However, the usage of the jaali by current' modernist' architects leads one to believe that its appropriateness, rather than its novelty, drives utilization.

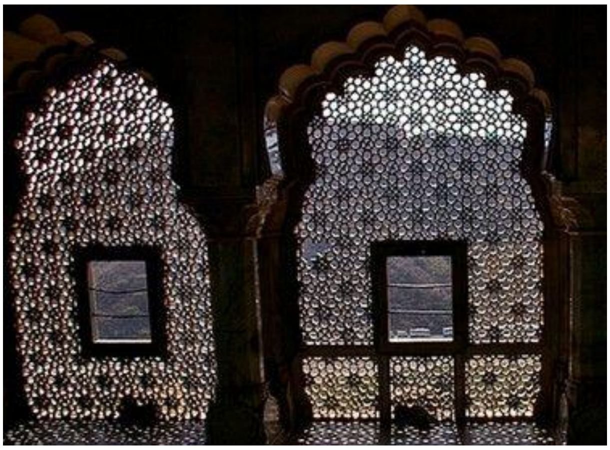


Figure. 1: Jali during Mughal Period

Cultural aspects

- Men and women must be kept apart in the eastern countries; this practice can be attributed to Islam's influence. Purdah, which formed an element of women's etiquette in India, was a reflection of social status and riches.
- The Hawa Mahal, often known as "the palace of winds," is a symbol of Jaipur. Its façade, which faces the main thoroughfare of the ancient city, is covered with intricate honeycomb patterns
- For the ladies in the traditional social structure, it served as a veil. From behind the screens, away from the gaze of strangers, royal women could see processions andcity life.

Depending on the cultural context, you may want to incorporate designs that hold cultural or religious significance. Jaalis often include motifs and symbols that are meaningful in the local culture. Be mindful of the cultural relevance of the design.

Climate: If the project is in a region with extreme climate conditions, such as intense heat or heavy rainfall, consider the durability and adaptability of the jaali design to these conditions.

Personal Preferences: The client's personal preferences and the vision of the architect or designer should also be taken into account. Jaali designs can be customized to suit individual tastes and preferences.

Material and Pattern

Jaali designs can be created using a variety of materials, each offering unique aesthetics, durability, and structural characteristics. The choice of material for jaali depends on the architectural context, design intent, and functional requirements.

Figure. 3: Terracotta

Stone Jaali: Stone jaalis are often made from materials like marble, sandstone, and limestone. These are durable and can be intricately carved to create detailed patterns. Marble jaalis are famous for their use in Mughal architecture, while sandstone is commonly used in Rajasthan, India.

Wooden Jaali: Wood is a versatile material for jaali work. It is often used for its warm and natural appearance. Teak, cedar, and rosewood are popular choices. Wooden jaalis are common in traditional South Asian, Southeast Asian, and Middle Eastern architecture

Metal Jaali: Metal jaalis are typically made from materials like brass, copper, or wrought iron. They are known for their strength and decorative qualities. Metal jaalis are commonly found in Middle Eastern Patterns- Islamic jaali patterns frequently use hexagons combined with various forms. According to the Koran, the six sides of a hexagon reflect the six days of creation, while the empty space on the seventh side symbolizes the seventh day, or Sabbath, when god erected his throne. Although it is not immediately apparent, the seventh element is crucial to the composition and promotes discussion. Another goal is to represent the shariah, which the prophets revealed and which represents the conclusion of their philosophical cycles, when the Natiq, who ushers in the seventh cycle of sacred history and reveals the spiritual significance of all past prophetic disclosures and religions..

Symmetry and Balance: Jaali patterns often exhibit a high degree of symmetry and balance. Symmetrical designs create a sense of order and aesthetic appeal. Common types of symmetry include bilateral symmetry (mirror image on either side of a central axis) and radial symmetry (repeating patterns around a central point).

Geometric and Mathematical Precision: Many jaali patterns are based on precise geometric and mathematical principles. These patterns often involve the use of geometric shapes like circles, squares, hexagons, and triangles. Mathematical relationships, such as the Golden Ratio, can be used to create visually pleasing proportions.

Modularity: Jaali patterns are often modular, meaning that smaller units or motifs are repeated to create a larger design. This modularity allows for the creation of complex and intricate patterns that are consistent and easy to replicate.

Process of Making Jaali.A subtractive sculpture approach is used to produce the negative and positive areas. The jaali's design is created from the leftover stone. With basic tools like a compass and a ruler, one may create many variations of a theme that are mathematically founded. Making errors during the complex grate-making process is not possible".

The process of making jaali involves intricate craftsmanship and attention to detail. The specific steps may vary depending on the material used, the design complexity, and the tools available,

- Step 1: Lattice pattern drawn on 1:1 scale
- Step 2: framework is made out of Aluminium for Replication
- Step 3: Jaalis are then Carved and Chiselled and Finishing touches are given.
- Step 4: Screens are fitted into its place.

Design and Planning:

The first step is to create a detailed design for the jaali. This design can be hand-drawn, created using computer-aided design (CAD) software, or a combination of both.

Consider the architectural context, cultural influences, and functional requirements when designing the jaali pattern. determine the material to be used, which will influence the design's intricacy and durability.

Material Selection:

Choose the appropriate material for the jaali, such as stone, wood, metal, glass, or other suitable materials. The material's properties, including strength, workability, and appearance, will impact the design and construction process.

Preparation of Materials:

If using natural materials like wood or stone, the raw material is prepared by cutting it into appropriate sizes and shapes.

Metal materials may need to be shaped, welded, or cast to create the desired components of the jaali.

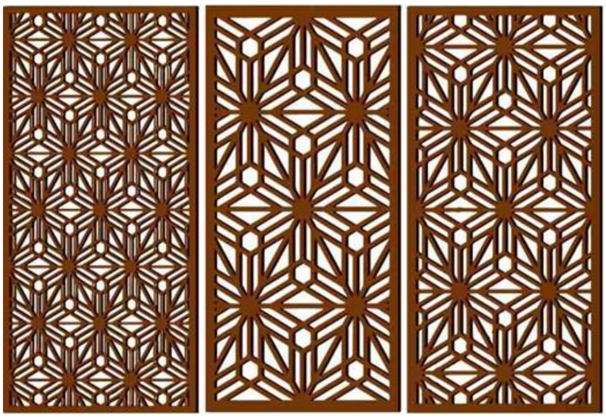
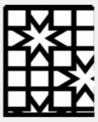
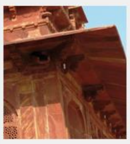


Figure.4: Wooden Hanging Jaali

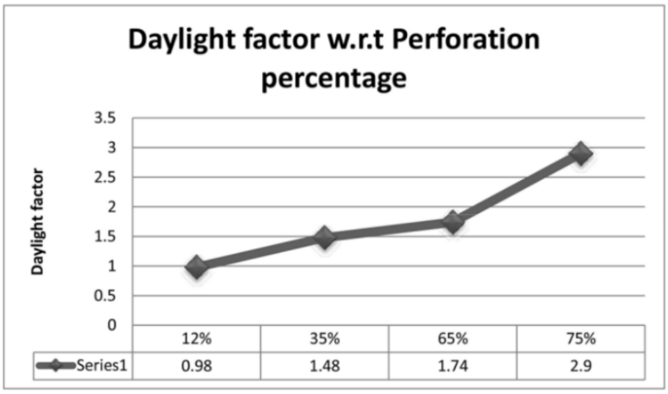
JAALI SPECIFICATIONS								THERMAL PERFORMANCE		
CLIMATE	JAALI	DETAILS	JAALI PATTERN	PERFORATION %	AREA OF EACH PERFORATION (SQM)	THICKNESS	SECTION	AVERAGE EXTERNAL TEMPERATURE	AVGERAGE INTERNAL TEMPERATURE	EXTERNAL INTERNAL TEMP. DIFFERENCE
Hot Semi Arid Climate	**Jaali-01**	**Hawa Mahal**, Jaipur Queens Chamber 16th century		12%	0.03 radius 0.003sq.m	60mm		34.0 C	31.2 C	2.8 K
	Jaali-02	**Hawa Mahal**, Jaipur Semi Open Space 16th century		35%	0.10x0.05 0.005 sqm	100mm		34.0 C	30.8 C	3.2 K
Humid Subtropical Climate	**Jaali-03**	**Tomb of Salim Chisti** , Fatehpur Sikri Transitional Space 14th century.		65%	0.04x0.04 0.0016sq.m	100mm		32.8 C	30.0 C	2.8 K
	Jaali-04	**Tomb of Islam Khan,** Fatehpur Sikri Prayer space 15 century.		75%	0.06x0.06	100mm		32.8 C	31.8 C	1.0K

JAALI SPECIFICATIONS			DAYLIGHT PERFORMANCE			AIR PENETRATION			CONCLUSION
CLIMATE	JAALI	DETAILS	SHADING ELEMENT	OUTDOOR ILLUMINANCE AVG.	INDOOR DAYLIGHT FACTOR	ORIENTATION OF THE SCREEN WIND DIRECTION	AVERAGE EXTERNAL WIND VELOCITY	AVERAGE AIR PENETRATION	ANALYSIS
Hot Semi Arid Climate	**Jaali-01**	**Hawa Mahal**, Jaipur Queens Chamber 16th century		10750 LUX	0.98	West winds screen facing west	2.02m/s	58%	This Jaali allows 60% of the outside air velocity but has a low perforation. So only a small amount of air enters the space and provides sun protection . As a result, it provides the main ventilation of the room, providing comfort.
	Jaali-02	**Hawa Mahal**, Jaipur Semi Open Space 16th century		10750 LUX	1.48	West winds screen facing west	2.02m/s	65%	This Jaali is used in semi-open spaces as it has relatively large openings to allow a greater amount of air. Angled perforations block direct sunlight and blocks vision.
Humid Subtropical Climate	**Jaali-03**	**Tomb of Salim Chisti** , Fatehpur Sikri Transitional Space 14th century.		27500 LUX	1.74	North winds screen facing west	1.94m/s	50%	The high perforation rate ensures good night ventilation and the sunshade elements keep sunlight out throughout the day.
	Jaali-04	**Tomb of Islam Khan,** Fatehpur Sikri Prayer space 15 century.		27500 LUX	2.90	North winds screen facing north.	1.94m/s	73%	The high perforation and small shade allow direct sunlight to pass through all day

PERFORATION %	12%	35%	65%	75%
SIZE	0.003 sq.m	0.005 sq.m	0.0016 sq.m	0.0036 sq.m
THICKNESS	60mm	100mm	100mm	100mm
HUMIDITY LEVEL	DRY	DRY	HUMID	HUMID
PROVIDE SHADING	YES	NO	NO	NO
PREVENT GLARE	YES	YES	NO	NO
DAYLIGHTING	NO	NO	YES	YES

PERFORATION DIMENSION	0.03 radius	0.10*0.05	0.04*0.04	0.06*0.06
PERFORATION SIZE	0.003 sq.m	0.005 sq.m	0.002 sq.m	0.004 sq.m
OUTSIDE WIND VELOCITY (m/s)	2.2	2.2	1.7	1.7
AVERAGE AIR PENETRATION %	60%	67%	44%	70%

Figure.5: The table showing the factors that decide the perforation percentage of the Jaali



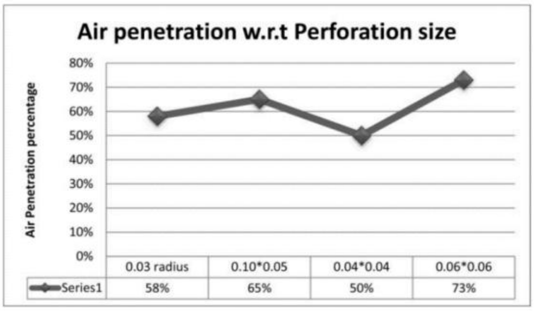


Chart -1: Graph showing the daylight factor with respect to perforation percentage

- When calculating the perforation %, the size of each perforation is not taken into account. Perforation percentages can be constructed in a variety of ways and hence function differently.
- The perforation percentage in Jaali 1 is 12 percent due to the hot, dry environment, with holes measuring 0.003 m2.
- The same 12 percent perforation Jaali can, however, be created with a larger perforation area (bigger perforations), which may not operate as well as the Jaali with smaller holes.
- The Jaali 3 and 4 contain perforations of 65 and 75 percent, respectively. The Jaali 4 allows for 73% of the outside air velocity, while the Jaali 3 only allows for 50% of the outside air velocity. In reality, the size of the hole has an effect.

The beginnings of the Jaali demonstrated its variety as well as its prominence in traditional hot-climate architecture. Every instance of the Jaali found illustrates its sensitivity to changes in heat circumstances as well as the functions it performs. In some cases, the Jaali are also utilized in the inner walls to enable air passage within the area due to pressure differences between the compartments.

The purpose of this research is to learn more about the Jaali by examining its key qualities, such as providing ventilation and light, and to comprehend how it influences the thermal efficiency of buildings.

- Correlations between the Jaali and the space and function were identified as a consequence of measuring the Jaali through case studies. The three research findings are as follows:
- The link between the size of the Jaali (perforation %) and the quantity of air, shade, and day illumination it provides.
- The quantity of daylight or the amount of air velocity necessary in the area might affect the comfort of the space.
- The size of the perforation is chosen to meet this criterion, and the percentage of perforation is directly related to the quantity of daylight that enters the space.

To correctly integrate Jaalis into design to promote comfort, one must first understand them. The Jaali is a significant feature of Mughal architecture that keeps the interior spaces cool. It controls airflow and lowers interior temperatures. The work contributes to the development of an optimal Jaali pattern that architects and building performance engineers may use to produce building screens that improve interior air quality and minimize energy consumption.

The findings of the article reveal that the perforation % and size of Jaali screens may be changed to produce well-lit, thermally pleasant indoor environments.

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Need of Passive Cooling Techniques and it's Feasibility in Residential High Rise Structures in Tropical Climate

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Abstract— The research is focused on Tropical climate where the humidity is higher. Mostly the areas located nearby sea shores or river sides have to face many issues to achieve thermal comfort without increasing load on non-renewable energies. Comfortable indoor conditions were achieved in such areas in vernacular architecture structures. Usually cross ventilation, pre cooling strategies were applied. But the modern buildings constructed by using modern materials are resulting into higher consumption of non renewable energy. As per current scenario it is very important to conserve the non renewable energy as well as reduce its use to the particular extent. So implementing passive cooling techniques in such areas is the today's need.

Traditional buildings were more focused on various design features resulting into achieving thermal comfort but in today's construction practice, people are focusing on foreign countries designs without considering the need of current climatic conditions of their particular place. This paper is trying to bring the attention towards this issue. And explaining the importance of passive cooling technique along with its feasibility and also focusing on payback period.

Keywords: Vernacular Architecture, Tropical climate, Thermal comfort, Passive cooling, Payback.

INTRODUCTION

The research area, New Mumbai is located on west coast of Indian subcontinent, surrounded by coastal side on one side and also few lakes at specific intervals. It is a part of metropolitan region. The height from sea level of this regi nmon is around 14.0 M. Due to such a large water source, the climate of New Mumbai falls under Tropical climate. New Mumbai usually experience two seasons – the monsoon and the non-monsoon in which winter and summer comes under non monsoon season. The integration of a choice of passive cooling methods are put into operation in order to achieve thermal comfort which has always been present in the vernacular architecture for a period of a time. After taking various factors like climate, culture, region, availability of material, skills and tradition of local workers etc., the vernacular architecture was developed and gradually improved as per changing climatic scenarios. Hence, during that period, the buildings were more energy efficient. But as the time changes, the requirement of that particular area is also changed. As population increased, it need more space for people to earn their home. (Jodeph Koduveliparambil, 2019)

The term passive cooling strategies refers to: Reduce of sun-powered heat gains by developing sun adjusted in built appliances, shield, appropriate construction materials, and shading.

The decline in heat gains by controlling light and other electrical devices.

Throwing out of surplus high temperature from the built form by means of convection, evaporative cooling, air development, cool wind, earth coupling, an impression of heat radiation, and so forth.

Aim

Analysing the feasibility of passive cooling techniques in residential buildings of New Mumbai.

Objective

Understanding and analysing the various passive cooling techniques in Tropical climate.

Exploring it's feasibility in New Mumbai area.

Analysingits importance.

Methodology

During this research, the initial work is started with gathering of various important data through literature, internet, various journals, case studies and standards for recognizing multiple options of passive cooling techniques which can be implemented in residential buildings in Tropical climate. Following fig – 1 expresses the in depth methodology implemented to carry out the research.

Scope

The paper focuses on various solutions of passive cooling techniques used in residential structures in Navi Mumbai.

The study is limited to vernacular architecture of Navi Mumbai.

The study is more focused on multiple methods in built form and Vastushastra in vernacular architecture.

Limitations

The study is focused on residential buildings of New Mumbai only.

The study is limited up to the analysis of impact of various passive cooling techniques through demonstration and computation in software like eQuest.

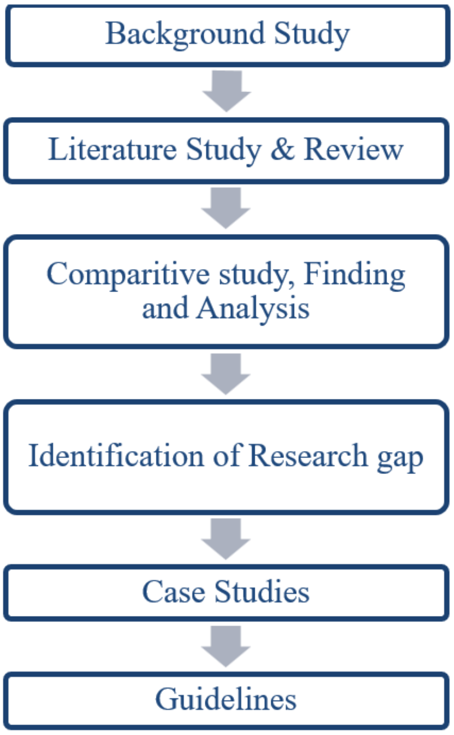

Figure 1 Methodology for Research

LITERATURE REVIEW:

Design guidelines:

New Mumbai falls under tropical climatic zone. And main objective for designing structure in such climate are:

Table 1 Design guidelines for tropical climate Reference: (Koenigsberger O.H., 2013)

* Resist Heat Gain:	
Decrease exposed surface area	Orientation and shape of the building
Increase thermal resistance	Roof & wall insulation , Reflective surface room,
Increase buffer spaces	Balconies and verandahs
Increase shading	Walls, glass surfaces protected by overhangs, fins & trees
Increase surface reflectivity	Pale color, glazed china mosaic tiles etc.
* Promote Heat loss:	
Ventilation of appliances	Provide windows/exhausts
Increase air exchange rate (Ventilation throughout the day)	Ventilated roof construction, Courtyards, Wind towers & arrangement of openings
Decrease humidity levels	Dehumidifiers / Desiccant cooling

Landform

When the availbale site is in slopy area then location of the building should be in windward side

And when the slight is surrounded by existing structure, identify the best possible wind direction and accordingly locate the building so as to achieve maximum ventilation.

Waterbody

As research is focused on structures in tropical climate where humidity levels in the atmosphere are already high, there is no need of any water body.

Open space & built form

Most important strategy in tropical climate is to achieve cross ventilation naturally, and for this there should be proper spacing must be designed between two structures.Form should be designed in such a way that it creates positive and negative pressure areas to achieve maximum ventilation. (Koenigsberger O.H., 2013)

Spatial Planning

While designing the structure, zoning should be done properly and the areas which generates heat should be located separately and ventilated. In multistoried structures, stack effect must be achieved by designing courtyard in the center which can help to withdraw heat away from the residential structure & promote the cross ventilation.

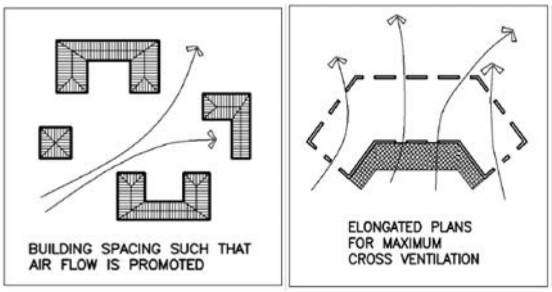

Figure 2 Forms & Spacing between structures

Roof

Usually the sloping roof is preferred in tropical climate. The huge shade shields the dividers and openings from sun radiation and rainstorm. But when it comes to high rise structures, simple flat roof with solar reflective paint or roof garden or roof pond or green roof etc multiple strategies can be applied depending on site conditions. Rooftop must be made with high reflectivity & low warm limit materials to avoid heat gain and transfer through horizontal facades. Type of roof ought to be planned in a manner to advance wind current. (Ospania, 2018)

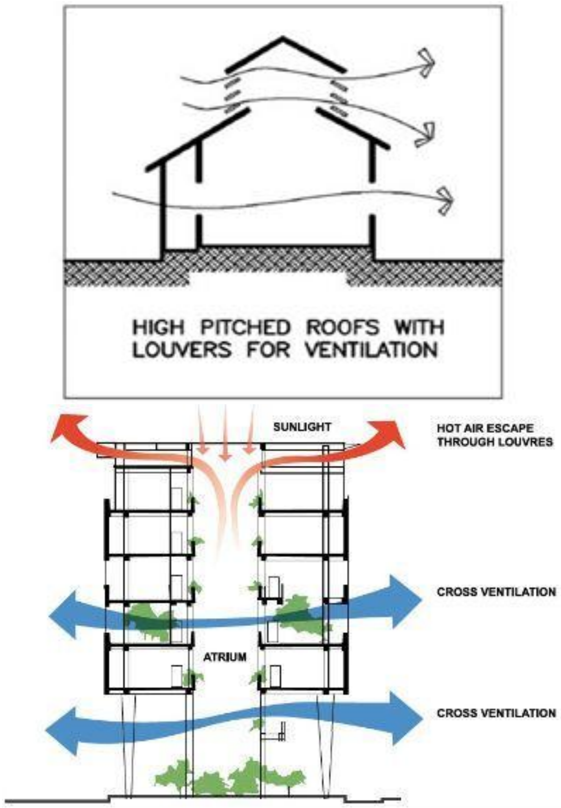

Figure 3: Ventilation through Roof

Walls

Walls should be constructed in material which posseses minimum heat storage capacity as well as better U value so the heat transfer is also remains low. There should be less obstruction in the air movement and walls should be protected from direcct sun radiation by strategies like mutual shading.

Color & Texture

As a generic statement, lighter colors absorbs less heat. Hence all walls should be coated with lighter shades or should be white washed & the roof surface can be broken glazed tile i.e. kind of a mosaic tile structure.

Openings

In tropical climate, cross ventilation and pre cooling of wind is the key strategy to achieve thermal comfort. Creating the positive and negative pressure during design helps to achieve maximum cross ventialtion throughout the year. Considering average wall to WINDOW ratio, lesser size windows to be designed on windward side whereas larger on leeward side which results in creating plume impact for regular ventilation.

Current scenario

As New mumbai is one of the growing city, whose development ratio is as follows:

Table 2 Development of New Mumbai area Source: Googel earth & Individual analysis

Years	Residenti al Area in %	Industrial Area in %	Open spaces in %	Population : Floating population	Remarks
2004	27	18	55	27:73	Migrant workers
2016	39	23	38	38:62	Few workers settled down
2020	47	28	25	43:57	Ratio of settlement increasing rapidly

Above statistics shows that after 2009, people started investing in to residential flats, and hence in the many areas there are high rise structures but as no strateies were implemented during design, they are facing many problems at the same time increasing the load on non renewable energy sources.

Navi mumbai airport is the upcoming hotspot due to which the development growth is increasing rapidly.

As a part of analysis of existing buildings, out of entire structure, around 33% area of the structure comes as non load bearing walls, 8% roof, 2% ground and 57% windows. This expresses that for achieving the cross ventilation, maximum area is coming under window but ultimately it is resulting into warm and humid air just because humidity levels are very high i.e. 87% maximum and 64% minimum.

This paper focuses on various strategies which will further reduce the load on non renewable energy.

RESEARCH FINDINGS

This paper elaborates the needs of various passive cooling techniques along with it's feasibility to achieve the thermal comfort as well as human comfort inside the structure. The strategies are explained for the high rise structures as it is the current need.

Forms & Orientation

As per the site conditions, and availability of the space, the building form should be designed in such a way that it will have the minimum exposed surface area on the sides form where harsh radiations will be incident. i.e. souther façade. Further more analysis of various forms should be done to cope up with all the issues and come up with the best possible shape. For this analysis, one can use software like eQuests or Rhino or Grasshopper.

For example, below analysis of various forms are shown from which best possible form is derived.

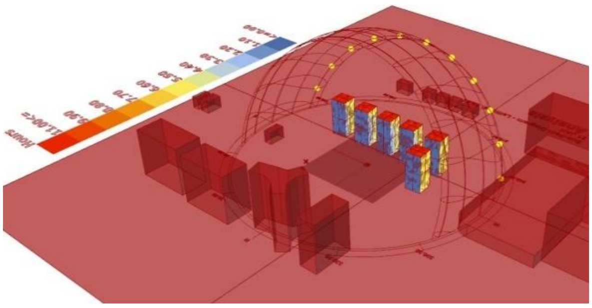

Figure 4 Incident heat on rectangular shape building on selected site

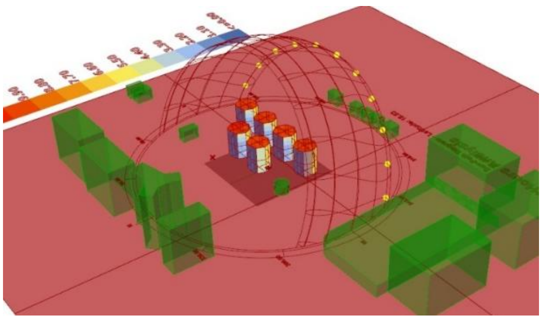

Figure 5 Incident heat map

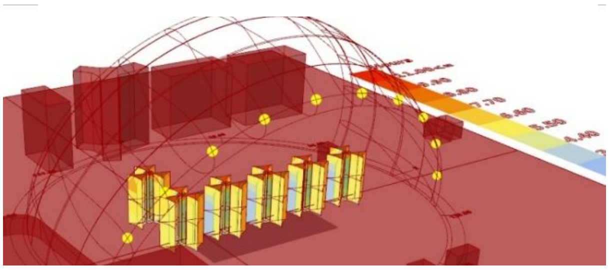

Figure 6 Incident heat map on irregular shape buildings on selected site

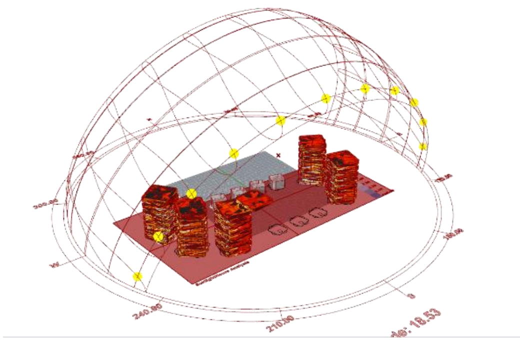

Figure 7 Incident heat on twisted square shape building

From the above analysis, it is proved that the form of the building reduces or resolves the heat gain problem by 23%.

Internal designing

Further location of internal rooms plays important role. Along with vaastushastra, current site conditions also must be studied and accordingly the internal part should be designed. Buffer spaces should be designed on southern façade and habitable rooms to be designed on norther façade to receive diffuse daylight through out the year. (B., 2008)

Service core to be designed in central part which further results into achieving stack effect by creating negative pressure inside the structure. This will help in achieving cross ventilation thoughout the year.

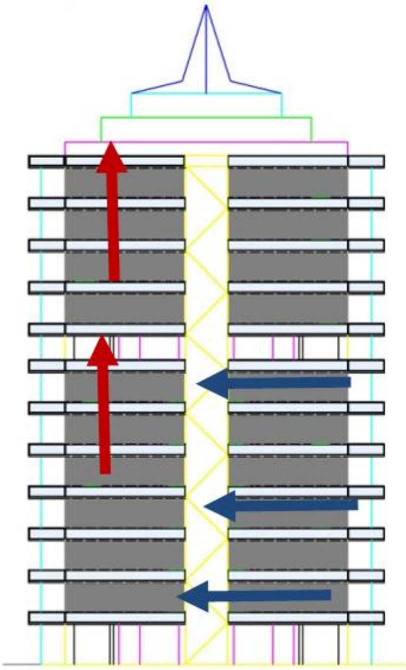

Figure 8 Stack effect in high rise strSuctures

Designing of building envelope

Depending on U value of various sections, final material can be identified for the construction of building envelope. Herewith various sections were designed and their U value is been calculated in the laboratory. From the entire study, it is been found that on southern façade, Double brick wall with 50 mm air gap with insulation will be the best possible alternative to reduce the heat gain as well as the thickeness of the wall can utilized at the opening areas for sit-out or storage purposes. For rest of the direction, fly ash brick with 23% of vermiculite components will be the best cost effective solution having U value of 0.39. The construction cost will be added by 38% at the beginning but the calculated pay back period comes around 4.3 years to 5.1 years. (Dhar, 2008)

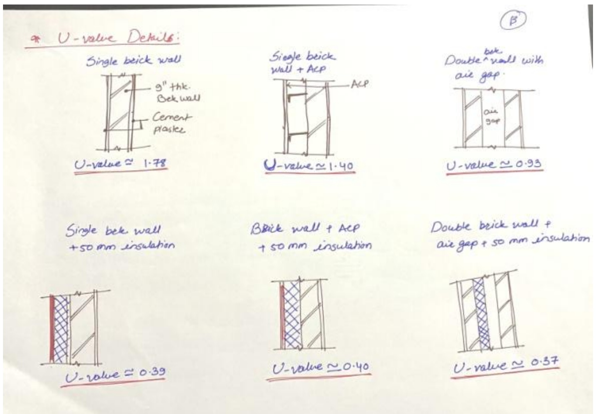

Figure 9 Various building envelope sections

Shading

Another simple strategy to reduce heat gain is to shade the surfaces which are directly getting affected by harsh radiations. This can be done by designing overhangs, chajjas, on southern and norther façade where as on eastern and western façade, sun angle is very low so use of verical fins, louvers will be more useful and do help to block the heat at the same time allows sunlight to penetrate inside the room.

Roofing

Roof is the second most area from where maximum heat transfers to the structure, to control the penetration of the heat during various seasons, multiple strategies are available which can be used depending on the site conditions, surroudings and cost factor.

Green Roof This is most common and tradtional strategy in which entire terrace surface area will be landscaped with propers construction techniques like water proofing, erection, load calculations etc. Further the native species of planters or screepers can be planted which will reduce the heat transfer by 43% to 58%. All above results were calculated in the software.

Roof pond In this trategy, roof area will be covered with water bags and insulation shutter. During day time, shutter will be closed, whatever heat transfers inside from the shutter will be stored in the water bags which were placed below the same and during night time, the insulation shutter is kept open so that the heat trapped in water bags will be again released to the atmosphere. In nay case if temperature in flat below terrace reduces drastically then the insulation is kept closed and all heat stored in water bags will be decipitated into the rooms via slabs.

Solar reflective paint : One of the cost effetive and simple way to reduce heat gain but ir needs maintenance every 5 year.

Tile cladding – Again the various wastage tiles can be brought together and simple design can be prepared from the same. As the tiles are reflective, the heat incident on same will be refleccted to atmosphere and not will be stored anywhere.

5.0 Conclusion:

The decision of roofing materials relies on cliamtic state of the zone and dependent on the decision of the customer on premise of his necessity.

All above mentioned strategies should be implemented during desiging and execution of the structure. Though initial cost goes on higher side, payback period stands somewhere around 4.3 years to 5.1 years.

Solar Panels – A little bit costly affair which needs large investment at the beginning but the payback perioid of the same is less than 3.5 years.

Orientation, forms and structural arrangement as well as internal l=planning plays an important role as a strategy to reduce the heat gain and improve ventilation.

Arrangement of false roof under rooftops helps in decreasing the temperature.

The guidelines will be valuable for developing houses in warm and humid cliamte.

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Sustainable Roofing Solution to Reduce Energy Consumption for Residential Structures

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Abstract— In the composite climate of India, as diurnal range is high, it becomes important to control heat gain or loss from Roof area. By creating a proper methodology this paper investigates the sustainable roofing solution to minimize the energy consumption in residential units. To achieve the best possible outcome, numerous 3D mockups were designed with variation in floor plan areas and lower roof levels from the original pitch. To achieve best possible results in terms of cost & performance, above models were studied without disobeying codes and local bye-laws. To get detailed structure models for the same, Building Information Modeling software from Autodesk (Revit 2022) is used. Further Autodesk Insight Platform was selected to analyze these models in detail. Energy Use Intensity and cost based result were provided by Autodesk Insight Platform while comparing against local bye-laws, N.B.C., ASHRAE 90.1 & Architecture standards. The identified cost may vary by +/- 6.35% due to on site material issues and labor cost & Natural calamities etc. Though final outcome explains that in the designed models, EUI and cost mean is higher than original models which may be due to heat gain or losses and absence of natural ventilation.

Keywords: Roof design, Composite climate, Energy efficiency, EUI, BIM.

INTRODUCTION

As we know, Roofing design is a crucial factor to consider while designing residential structures. Along with which, reduced cost construction is becoming a key point and so cost effective design and construction techniques are highly appreciated by the builders as well as owners. The main concern of this research is to analyze ten different residential units having various built up areas just to examine whether the variation in slope of roof results into increased energy performance or decreases the energy performance. As varying roof pitch lower its cost and also modify the energy performance of the associated building. (cost, 2018). To achieve the further details BIM is been used. The research focuses on tropical climate in India specifically New Mumbai city, J.N.P.T. area. It evaluates their actual costs and their solar proficiency versus more similar roof designs. The way roofs are designed and built has not transformed much intensely. So, it is believable that the present wide spread roof geometry may not be the most inexpensive or energy effective. The chosen roof were almost similar in shape because most of the roof in outer area of new mumbai before development have an usual roof pitch of 230 to 300 mm or more. Henceforth the material involved in the execution of such roof possesses relatively higher quantity and cost.

The normal cost of the new roof in the same region is increasing. (cost, 2018). Contemporary roof, irrespective of their geometrical shape, comprise of 5 parts which consists structural framing, sheathing, underlayment, gutters, and finished surfaces. (D, 2018).

Though, the final construction cost of the new roof can be let down by implementing some alterations to the roof components. Without disturbing the basic rules let down by standards and local bye-laws, lowering the pitch of the roof is good alternative to reduce the construction cost. High roof pitches are not essential in most of the zone of the mentioned region. Also, to achieve the lower cost of the roof, material to be used in new roof construction should be reconsider. Materials may include various framing lumber sizes, different kind of thermal protection, and/or different kinds of surface finishes. To develop new efficient roof, building information modelling software can be used. Using the BIM will facilitate collaborative process in which multiple trades can be involved in planning, design and construction. (S., 2018). Designers and contractors can take assistance of the same BIM software to produce 3D mockups which support owners in making well-versed decisions. Autodesk AutoCAD, Autodesk Revit, Revit add-on MWF, Rhinoceros, and Rhinoceros add-on Grasshopper are some of the software which are BIM related and used for the above purpose. Using this software, the process of designing of roof becomes easier. In above to all, it can make the roof modular which in return, can make it inexpensive and safer for erection. For the purpose of this project, only two software programs were considered for design authoring, Autodesk Revit and the MWF add-on to Revit.

Since the constructiontrade is a heavy buyer of raw resources and one of the major contributors to waste generation which is about 43% of the materials that are dumped in landfills are construction waste (Yuan Z., 2017), there is a strong public interest in reducing the waste. By using BIM/parametric software (Revit, Rhinoceros add-on Grasshopper) there can be reduction in construction waste.(Yuan Z., 2017).This may be achieved by predesigning the members in Autodesk Revit and then employing the quantity take-off function to extract the amounts of materials before the construction phase begins.

Using Revit can benefit the users with real-time quantity amounts that automatically adjust when design changes are made. This assists in cost-sensitivity analysis that could save money, time, and materials.(Zhao Q., 2015) In this research, the vision was implemented to examinerooftop design efficacies for lesser energy consumptions, due to its compatibility thru Revit and its parametric energy scrutinyability. Furthermore, to achieve consistent results related to the energy model results, other variables like envelope material, w.w.r, glazing material were kept stable over the chosen models.

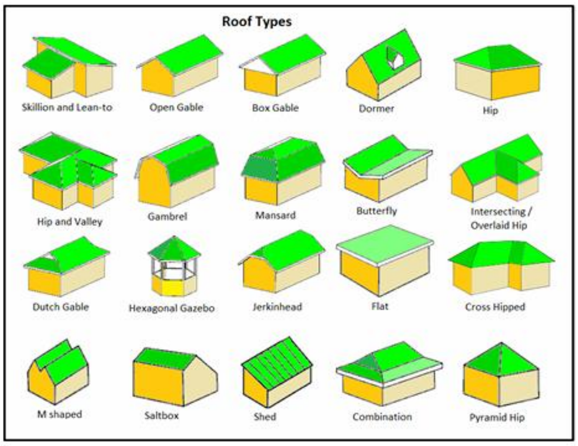

Figure 1 Roof Types
Reference: (Roof Replacement Cost, 2018)

LITERATURE REVIEW

Many residential structures constructed in vernacular pattern in southwestern part of New mumbai city, J.N.P.T. area were designed in similar roof pattern. As image shows, most common types were gable, open gable, hip, hip & valley, cross-hipped. Benefits of such roofs were slope helps rain water to fall down quickly and attic space was used for ventialtion as well as barrier for direct heat gain through roof. (estimator, 2021). The mentioned source gives result of various cities out of India, but as researcher, identified the cities having similar climatic conditions and further reference is used. However, a gable roof style is challenging in high winds areas as some load carrying members of the roof may not be properly protected and, if the projection of the roof is bigger in ratio, the wind could cause uplift. The benefits of the hip patterned roof is the strength into the design, means hip roofs responds better in high wind climatic conditions. As, material requirement for constructing a hip roof is more, a hip roof style is generally more expensive to build in respect to a simple gabled roof (estimator, 2021).

As seen in figure 2 below, the roofs of buildings are supported by “rafters, ridge boards, ceiling joists, struts, and hangers”. The ceiling joists extend from the outside wall of the structure to the load-bearing wall in the middle. The roof pitch is established by the rafters, which also support the major assembly. At the summit, the rafters converge at the highest line on a roof structure is called the ridge board. The web, which is made up of the struts and hangers, provides structural support for the ceiling joists and rafters. Wood is the most often utilized material in the construction of these constructions. However, depending on the owner's preferences, the roof's finishes may differ. In the Southeast, metal panels or asphalt shingles are the most often utilized roof finishing materials.

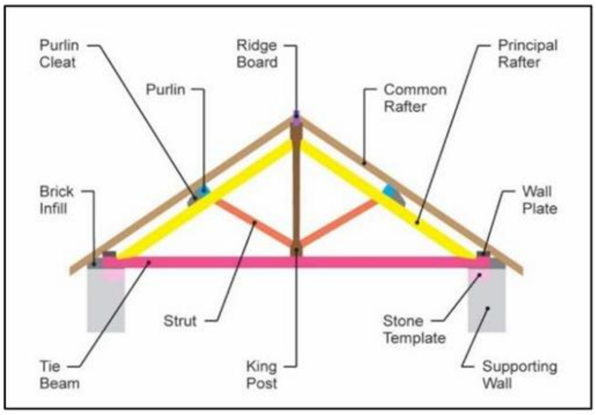

Figure 2 Roof structure A Cloud based building energy analysis tool
Reference: (Autodesk, 2019)

Numerous businesses develop software with an emphasis on developing performance studies. Among these software programs is Autodesk Insight, a potent cloud-based instrument that helps users enhance any model created parametrically in Autodesk Revit's energy and environmental performance. Introducing Autodesk Insight 360 (2015) lists a number of capabilities available on Insight, including real-time feedback, BIM connections, comprehensive building energy analysis, and several others. Insight concentrates on day illumination, solar radiation, and heating and cooling loads to achieve comprehensive building energy analysis. (C., 2017) After Insight has completed all of the aforementioned elements' analyses, the findings can be generated, as seen in figure 3 below. A number of Insight features, including EUI, model history, and benchmark comparisons, are shown in Figure 3. and the qualities of glazing. (C., 2017) It collects all the parameters that affect the building's annual energy consumption and divides them by the building's total area to get a normalized amount expressed in square footage. The outcome displays the EUI's maximum, mean, and minimum.

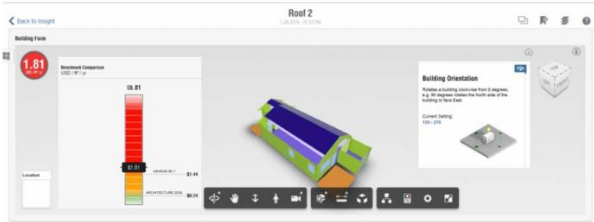

Figure 3 Autodesk Insights Output
Reference: (Commitment, 2019)

Current scenario

In EUI dollars, the maximum denotes the biggest amount, the mean represents the average, and the lowest, which occasionally may be negative, is the least amount required for a specific design. Users receive findings that are expressed in terms of annual and per-area energy use. The insights calculations also display comparisons between the EUI of the present model and the benchmarks ASHRAE 90.1 and Architecture 2030 (C., 2017) The energy standard for buildings, ASHRAE 90.1, is the first one to be compared, with the exception of low-rise residential buildings. Four main components are examined by Insight: the building envelope, HVAC systems, lighting and electricity systems, and overall building energy performance. By location, each of these elements may change the structure. The thermal requirements for walls and roofs might vary depending on the area and are expressed in terms of either the minimum insulation R-value 5 or the maximum permitted U-factor 4. (C. C. , 2021) The building's minimum R-value for the air ducts and pipes in the HVAC systems position of the code. Energy-efficiency ratios (EER) must also be met by them. While the integrated energy-efficiency ratio (IEER) monitors load efficiencies annually, the energy efficiency ratio (EER) assesses energy efficiency during peak loads. Seasonal energy-efficiency ratios (SEER), which measure efficiency over a range of external air temperatures, must be met by residential equipment. According to Boldt and Rosenberg (2018), all values are presented in Btu/W*hr, with 3.4 Btu/W*hr = 1.0 COP (Coefficient of Performance). (Boldt, 2018).

Insight compares its models to Architecture 2030, a standard that was established in 2007 and is currently being implemented by 839 US communities. By 2030, the Architecture 2030 challenge seeks to completely cut global greenhouse gas (GHG) emissions. It stipulates that by 2050, all newly built buildings have to be carbon neutral and built to strict energy efficiency criteria. Autodesk Insight evaluates the model's carbon footprint in real time in order to receive the Architecture 2030 benchmark. (Commitment, 2019) Five stages are provided by Architecture 2030 to help achieve this.

Using Autodesk Insight, create an EUI baseline as the first stage. (Commitment, 2019). Five stages are provided by Architecture 2030 to help achieve this. Using Autodesk Insight to create an EUI baseline is the first phase. To get optimum energy efficiency, the second phase is to implement low- or no-cost passive design strategies. These low- or no-cost passive design techniques can be used to optimize solar heat gain, daylighting, building orientation, etc. Integrating energy-efficient systems and technology is the third step. LED lighting, energy-efficient air conditioners, programmable thermostats, and various other devices can be examples of this technology. Incorporating on-site and off-site renewable energy sources, like solar panels, will be the fourth phase in meeting the remaining energy needs (Commitment, 2019). Lastly, iterative energy modeling for the duration of the design is the next phase.

Materials

In EUI dollars, the maximum denotes the biggest amount, the mean represents the average, and the lowest, which occasionally may be negative, is the least amount required for a specific design. Users receive findings that are expressed in terms of annual and per-area energy use. The insights calculations also display comparisons between the EUI of the present model and the benchmarks ASHRAE 90.1 and Architecture 2030 (C., 2017) The energy standard for buildings, ASHRAE 90.1, is the first one to be compared, with the exception of low-rise residential buildings. Four main components are examined by Insight: the building envelope, HVAC systems, lighting and electricity systems, and overall building energy performance. By location, each of these elements may change the structure. The thermal requirements for walls and roofs might vary depending on the area and are expressed in terms of either the minimum insulation R-value 5 or the maximum permitted U-factor 4. (C. C. , 2021) The building's minimum R-value for the air ducts and pipes in the HVAC systems position of the code. Energy-efficiency ratios (EER) must also be met by them. While the integrated energy-efficiency ratio (IEER) monitors load efficiencies annually, the energy efficiency ratio (EER) assesses energy efficiency during peak loads. Seasonal energy-efficiency ratios (SEER), which measure efficiency over a range of external air temperatures, must be met by residential equipment. According to Boldt and Rosenberg (2018), all values are presented in Btu/W*hr, with 3.4 Btu/W*hr = 1.0 COP (Coefficient of Performance). (Boldt, 2018).

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Results

Energy Model Output: As illustrated in Figure 3 above, Autodesk Insight shows the building performance results once the study is finished. Building orientation, daylight & occupancy control, HVAC, infiltration, light efficiency, plug load efficiency, PV (panel efficiency, payback limit, and surface coverage), wall construction, roof construction, window glass, window shades, and window wall ratio (WWR) for different asphalt shingles and metal panel roofs taken into consideration in this study are a few of the outputs.

- Daylight and Occupancy Control "shows the process of using a daylight dimming and occupancy sensor system" for a more efficient EUI and cost mean; Building Orientation "shows the process of rotating the building from 0 to 90 degrees (north to face east)" for a more efficient EUI and imply costs (Autodesk, 2015).
- HVAC displays "a range of HVAC system efficiency, which will vary, depending on building size and location"; According to infiltration is defined as "the inadvertent leaking of air into or out of conditioned space; often due to gaps in the building envelope." (Autodesk, 2019)

- Operating Schedule displays "the typical hours of use by building occupants"; Light Efficiency "shows the average internal heat gain and power consumption of electric lighting per unit floor area" (Autodesk, 2019).
- "The cost of power used by equipment (computers, small appliances, etc.) excluding lighting, heating, and cooling equipment" is displayed by plug load efficiency, PV displays "the solar panels' efficiency, surface coverage, and payback period".
- "The overall ability of wall construction to resist head losses and gain" is demonstrated by wall construction; "Overall ability of roof construction to resist heat losses and gain" is demonstrated by the roof's construction.
- Window glass exhibits "glass properties controlling, among other things, the amount of daylight, heat transfer, and solar heat gain into the building"; Window coverings demonstrate "how to cut HVAC energy use."
- The effect is dependent on additional variables like window size and solar heat gain characteristics; Window Wall Ratio illustrates how windows' characteristics combine to affect heating, lighting, and cooling. (Autodesk, 2019).

Experiemental research methods

Autodesk Revit software was utilized to create every model used in this study. The analysis of energy The Autodesk Insight cloud platform was used to finish this project. To develop a simultaneous real-time cost analysis simulation, the RS Means catalog was used. The software add-on (MWF) was utilized to build the roof's structural framework. A free trial was offered to students by StrucSoft Solution (https://strucsoftsolutions.com). The floor plans were collected from regional architectural styles and adjusted for the building techniques and materials used in the Southeast. There were ten chosen floor plans. From 868 square feet (2 bedrooms and 1 1/2 baths) to 4064 square feet (4 bedrooms and 3 1/2 bathrooms), they were all in line with residential buildings. The home floor plans were designed in a manner that was inspired by the Southeast part of the state. As a result, styles like Craftsman, Coastal Beach, Traditional, and Acadian are represented. Ten buildings were constructed, and each of the residential units' walls, ceilings, and floors was modelled using predefined, homogeneous layers. To ensure uniformity across the project's experimental models and analyses, every door and window had the same configuration. Two types of roofing materials were employed as the top layers: asphalt shingles and metal sheets. Five (5) asphalt shingle models and an additional five (5) metal panel models were configured for this project.

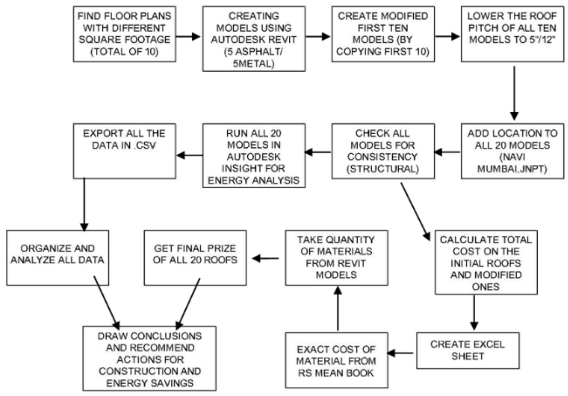

Figure 4 Research Methodology flowchart

The project was located in an area with residential building rules and municipal regulations that stipulated that a minimum of 4" of concrete slab on grade was required for residential constructions. However, for all of the slabs employed in the simulations in this investigation, a thicker concrete was chosen. This choice was made in order to prevent having an impact on the building energy The following stage was using MWF to produce the roof structures after all the models had been generated. Making the updated models came next once these structures were added to the models. With all of the roofs dropped to a pitch of 5 inches or 12 inches, these models were a perfect replica of the first ten (10) original versions. Because it was the lowest pitch permitted by the regulation in the state's southeast, this roof pitch was selected. Additionally, this pitch was selected in order to develop and test a more effective roof design. Afterwards, MWF was used once more to create the structure supporting the lowered ceiling (see flowchart in figure 4).

Results

Model's analysis for Energy Efficiency & Conclusions: Following completion and a consistency check, all twenty (20) models were prepared for Autodesk Insight analysis. The models were then given locations, and the Insight cloud was used to examine the results. During the analysis phase, all roof structures that had previously been created using MWF were included in the models. This procedure also made use of Autodesk Revit's energy optimization tool. After the study was finished, the website https://insight360.autodesk.com/oneenergy displayed the final product, which included real-time feedback, BIM interfaces, comprehensive building energy evaluations, and several other parameters that were first included in Autodesk Insight 360 in 2015. Exporting the intermediate results for additional analysis was the following step once all analyses were completed and made available for viewing in the cloud. After being exported into a.csv file, all of the data was moved to an MS Excel file for further processing. The Excel file had the maximum, mean, and minimum expenditures in US dollars for each model of powering the building for the entire year. The cost mean shows the yearly average of the building's electricity expenses. The lowest annual cost to power the facility was indicated by the cost min. It should be noted that the minimum cost may occasionally be a negative amount. Despite the fact that a cost analysis was. Ten (10) BIM models were created, using the original roof pitches (given by the designers themselves), and then duplicated with smaller roof pitches (5"/12"). Only the performance of the redesigned model was analyzed and compared using Autodesk Insight.

Estimating the material by comparing it with the initial models and using the RS Means database. prices for every model style. Because of the wide range of pricing, it was determined to leave out the cost of labor, tools, and equipment from the cost comparison analysis.

Discussions

Figures 5 and 6 summarize the findings; in these, "OG" stands for "original roofs" and "Mod" for "modified roofs." It was anticipated at the outset of this project that the updated models would be less costly to construct and would achieve an annual improvement in energy performance over the original models. But after the data was analyzed, it was found that, in terms of energy performance, the original models were frequently less expensive than the updated models. Two instances deviated from the norm. Less energy was used in Models 1 and 5 following design changes. Since the modified model's cost mean and EUI were both lower in Model 1 than they were in the original, the modified model's cost mean and EUI are also found to be lower. On the other hand, Model 5 maintains very near values for the EUI while having the same expenses mean as both the original and modified models. Out of all the case studies, only Model 1 surpasses or satisfies ASHRAE 90.1 and Architecture 2030 standards. The majority of floor plans and their corresponding models nearly met the ASHRAE 90.1 specifications, with the exception of a few small adjustments to the building orientation and envelope. The other models, however, satisfied ASHRAE 90.1 requirements. Because less materials were needed to construct the modified models—that is, because lower pitches meant less roof surface—the building costs were cheaper. However, the modified roof models were more costly than the original ones when taking into account pricing per square foot (unit prices).

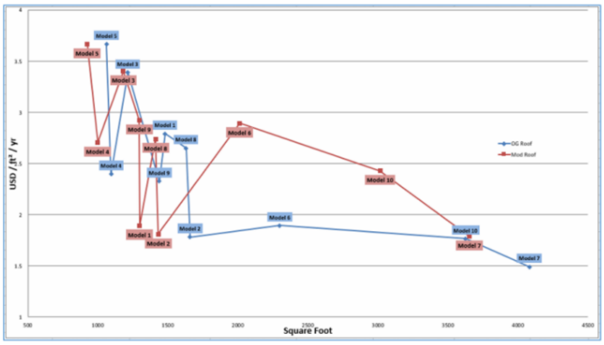

Figure 5 Cost mean to Roof square footage comparison

Further analysis of the data adds to the body of knowledge by showing that the 5"/12" roof pitch is not the best roof in terms of building performance. This outcome might have been brought about by the altered roofs' decreased area for air movement. It might have been exacerbated by heat gain or loss, which can be more common on roofs with 5 or 12 pitches. The EUI will rise in tandem with a building's increased heat gain/loss because of the increased strain on the HVAC systems. The building's occupant(s) would ultimately begin to lose money after the payback period is over, despite the fact that the low pitch would save them money during the building's construction. Thus, one recommendation would be against using lower pitched in humid climates like the Southwest of the New Mumbai i.e. J.N.P.T.

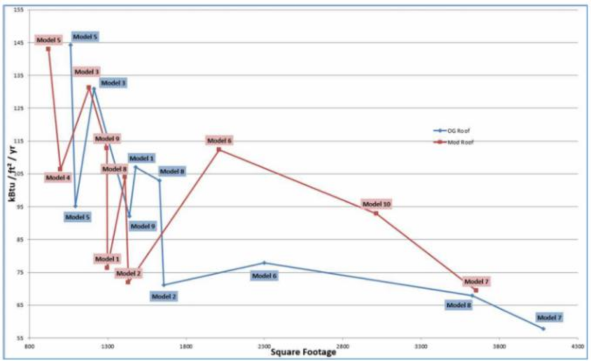

Figure 6 EUI Mean to Roof square footage comparison

CONCLUSIONS

Future studies may look into a different site, like a city in the northeastern United States, to see if gradually raising or lowering the roof pitch has an impact on how energy-efficient a structure is during really cold winters with a lot of snowfall. To ensure that the future project conforms with local/state related codes, it would be necessary to evaluate the local building codes before selecting a new location. The authors are also interested in how different materials may impact the performance of residential roof systems (an additional study constraint). Rigid insulation was the type of insulation examined in this experiment. Future projects might employ different sized lumber and different types of insulation with a higher R-value in the models because these aspects might result in better energy performances.

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Vernacular Architecture in Assam

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Abstract— Assamese vernacular architecture demonstrates the unique building methods used in the area, which take into account social, economic, tribal, and modern influences while utilizing native materials and practices. This architectural style, which is primarily composed of single-story homes, emphasizes living circumstances and cultural values, reflecting the many populations found throughout the state. Assamese vernacular architecture responds to seismic activity and topographical factors by using community resources. This study highlights the Assamese vernacular architecture's ongoing significance while acknowledging its incorporation of contemporary designs and materials. Assam's architectural landscape is developing, even though traditional methods continue to be followed, as evidenced by the increasing integration of new features. The purpose of the article is to investigate how these local customs may coexist with modern architecture's growing sway in the area.

Keywords: Vernacular, community, tribal, sustainability

INTRODUCTION

"Vernacular architecture" refers to the traditional architectural forms and techniques that organically arise in a given region or community. It resembles the local "language" of architecture that people use to construct their homes and other structures. It might be called "architecture without architects" because it could be created by regular people who aren't trained architects or builders. They use their practical skills and local materials to design structures that suit their needs. It also symbolizes the environment, culture, and resources of the area. People adapt their building methods to the specific conditions in the area. Using rich local resources, planning for the climate, and incorporating cultural motifs into the design are a few examples.

Within the Brahmaputra valley in northeastern India, Assam faces three urgent challenges: earthquakes, floods, and cyclones. Poor communities frequently lack access to contemporary building methods, and traditional "Assam-type" structures are threatened by soil erosion brought on by deforestation, climate change, and a shortage of local building materials.
The risks are further increased by Assam's closeness to a seismic zone that is quite active and by its susceptibility to strong cyclones along its coastal districts. In order to overcome these problems, a thorough investigation seeks to reveal the wisdom ingrained in Assamese traditional architecture. Creative solutions that incorporate modern, reasonably priced materials like stone walls and bamboo construction are suggested.

The situation is exacerbated by deforestation on the high hills surrounding Assam, which increases the risk of flooding by causing soil erosion and reducing the amount of water that rivers can hold. Furthermore, a thorough investigation of the ways in which traditional Assamese architecture has traditionally tackled these issues is required given Assam's vicinity to a Himalayan seismic hotpot and its vulnerability to cyclones as a result of its location near Bangladesh and the Bay of Bengal.

The paper progresses with a specific focus on following objectives:

- To study the historical background and cultural aspects of Assam's vernaculararchitecture style
- To identify the typical characteristics of the Assam

vernacular architecture style

- To learn the different methods andtechniques are used in this style
- To understand the topography ofclimatic factors which affects theconstruction methods

Investigating the composition, utility, and subtleties inherent in the wide range of materials and techniques that form the basis of the specific architectural style under consideration is the main objective of this study. A profound understanding of the interactions between culture, architecture, the environment, and deeply ingrained customs forms the basis of this undertaking. Using architecture to educate people about local history and culture could be a potent way to celebrate design and art in a way that the public finds meaningful. Although the majority of the state still adheres to traditional customs, the incorporation of contemporary design and materials has been increasing and is likely to continue until it becomes a significant component of the Assamese architectural style.

LITERATURE REVIEW

Vernacular architecture: what is it?

"Vernacular architecture" describes the different ways that people build houses and other structures in their own distinctive styles all around the world. It appears that each location has a distinct architectural style that has been in operation for a very long period. In a broader sense, it describes traditional building methods and architectural designs that have developed throughout time in certain locales or communities. It stands out due to its strong ties to the local environment, resources, and way of life. The vernacular architecture is often inherited and evolves organically over time. In comparison, increasingly standardized and international architectural methods and styles are in opposition.

What type of vernacular architecture is Assamese style?

The traditional architectural design known as the Assam style of vernacular architecture customs and construction methods that the northern Indian state of Assam has developed over generations. Assamese vernacular architecture is a reflection of the region's rich cultural legacy, close ties to the natural world, and customs. As contemporary building materials and methods proliferate, attempts are underway to conserve and promote traditional Assamese architecture as a crucial component of the state's cultural character. The importance of heritage to the people of the state is shown in the utilization of local materials and the prioritization of the local population.

Evolution Timeline

- Historical Origins (Ancient Period): The architectural history of Assam dates back to the ancient Kamrupa kingdom, where stone and bricks were used during the Varman, Pala, and Salasthambha dynasties. However, these structures often deteriorated due to challenges posed by earthquakes and heavy rainfall.
- Tai-Ahom Influence (13th Century): Significant architectural changes were introduced by the Tai-Ahoms in the 13th century. They constructed elegant wooden mansions in the Brahmaputra valley, using local materials like wood and bamboo. The Tarikh-i-Assam documents these structures, emphasizing the crucial role of the "changrung phukan" in overseeing construction.
- Innovative Village Resettlement (1609): In 1609, Momai Tamuli Barbarua initiated the Paik system, transforming agricultural landscapes. Villages featured raised plinths with diverse functional units and private estates, often incorporating bamboo forests and betel nut trees as prominent features.
- Materials Reflecting Geography: Dense forests and riverside settlements influenced the use of materials such as wood, bamboo, straw, and ikora. Elevated bamboo platforms called "chang ghars" were built to mitigate flooding, while hillside communities used timber for elevated housing.
- British Rule and Architectural Development: During British rule, efforts were made to preserve regional architectural styles. Circular No. 8 instructed officers to protect historic structures. The 1897 earthquake, however, led to the construction of sturdier buildings in Dibrugarh, Guwahati, and Shillong.
- Transition to Assam-Type Architecture: The 1897 earthquake prompted a reconsideration of building methods. Inspired by Japanese earthquake-resistant models, Assam-type architecture emerged, influenced by Tudor architecture, traditional Japanese building practices, and intricate joinery techniques.
- Interior Design and Changing Trends (1930s-1950s): Assamese houses in the 1930s and 1940s featured distinct elements such as tin roofs, ornate staircases, and elaborate joinery. Designs evolved over time, with the transition to smaller homes by the 1950s reflecting changing family sizes and preferences.
- Impact of the 1950 Earthquake: The catastrophic

1950 earthquake prompted a reevaluation of building materials and methods. Traditional materials like bamboo and thatch proved vulnerable, leading to a shift toward more earthquake-resistant materials and seismic design incorporation

- Transition to RCC Buildings and Conservation Challenges: In the second half of the 20th century, Reinforced Cement Concrete (RCC) structures

Figure. 1. Colonial Era Assam type house

Factors Affecting the Style

Topological Factors: Assam's vernacular architecture is shaped by the region's topography, particularly the influence of the Brahmaputra River and its tributaries. To counter seasonal floods, houses are elevated on platforms or stilts. The abundant timber and bamboo from the region's forests are primary construction materials, and the hilly terrains lead to the construction of multi-story houses in certain areas. The seismic activity in Assam necessitates the use of flexible materials like bamboo and wood for earthquake resistance.

Climatic Factors: Assam's diverse climate, characterized by tropical monsoons, intense rains, high humidity, and occasional floods, plays a crucial role in architectural choices. Elevated designs help mitigate flood risks, while features like cross-ventilation, open verandas, and raised floors address the high humidity. The availability of materials and the need for natural ventilation reflect the region's climatic nuances in construction.

Socio-Economic Factors: Vernacular architecture in Assam goes beyond mere buildings, embodying cultural and folkloric significance closely linked to traditions and values. It serves as a repository of traditional knowledge, adapting to evolving needs while reflecting community experiences. This relationship between architecture and culture illustrates how societal values are embedded in construction, offering insights into both past and present dynamics.

Tribal Influences: Assam's tribal communities significantly impact local architecture, contributing to the region's diverse cultural landscape. Indigenous socio-religious beliefs and Hinduism influence housing styles, often seen in stilt houses with gable roofs. Each tribal community exhibits unique architectural characteristics, despite similarities in construction methods. Examining major tribal groups separately allows for a deeper understanding of their distinctive styles and fosters comparative studies across communities.

Construction Techniques

Roof Construction: In Assamese vernacular architecture, roofs traditionally feature gables and historically utilized locally grown "kher" thatch as the primary roofing material. This thatch underwent a meticulous process involving sun drying, cleaning, and bundling to ensure durability and suitability. While modern materials such as corrugated iron, asbestos, and polythene have gained popularity, traditional methods persist. Timber trusses, bolted with rubber washers, are used to protect against rain. The intricate process of roof construction involves bamboo frames categorized as "shitalichal" and "hedali." The former employs woven bamboo strips, while the latter, known for comfort and robustness, utilizes bamboo rafters.

Bamboo Tying Strand (Tamal): Sustaining Tradition: Traditional Assamese construction avoids iron nails, relying instead on organic materials for binding. Bamboo strands, known as "tamal," play a crucial role in this regard. Carefully selected young bamboo, dried and treated, is transformed into tamal. Varieties like pitha, buku, and nalia serve distinct purposes in construction, highlighting the skilled craftsmanship and deep knowledge embedded in Assamese building practices.

Foundation: Anchoring in Tradition: Assamese homes typically lack formal foundations, with vertical wooden posts directly anchored into the ground. For larger structures, masonry or concrete pillars above ground level support these posts, connected with U-clamps and steel bolts. This blend of traditional wooden posts and contemporary metal connections ensures stability while meeting modern structural standards.

Posts: Crafting Stability from Bamboo and Wood: Bamboo or tree trunks, particularly bhaluka bamboo, are selected for posts in Assamese construction. A meticulous process involving grooves, fish-mouth cuts, and cleaning ensures their durability. Specific posts like mudhar khuta, kumar/mootpochar/moorpachar khuta, and panpocha/panipotar khuta serve distinct purposes, emphasizing the attention to detail in Assamese construction practices.

Walls: Bamboo, Reed, and Craftsmanship: Traditionally, walls in Assamese vernacular homes are constructed using bamboo or occasionally reed. Techniques such as the Kathi method, Chuch weaving, and flattened bamboo panels are employed. Reed, due to its availability and flexibility, is also utilized. These construction methods showcase intricate craftsmanship, with each technique contributing a unique aesthetic and structural quality to Assamese vernacular architecture.

Types of Vernacular houses in Assam

Karbi Vernacular house

Formerly known as the Mikir, the Karbi are a prominent ethnic group in Assam who are primarily found in the districts of Karbi Anglong, North Cachar, Kamrup, Nagaon, and Sonitpur.

Their traditional architecture contains lattice walls made of bamboo for natural ventilation, and they speak a Tibeto-Burman language with Mongoloid origin. The home is raised on towering supports that are positioned to collect rainwater and run down the hill's slope. With a main residence ("Hem-pi") for family and friends and a part ("Hong-pharla") for guests or higher social strata, the distinctive design divides utilitarian, holy, and private rooms. A wooden ladder that leads to the "Hong-phlang" entrance opens up to an open platform known as "Hong-jai" that connects the two. The floor and top levels of a Karbi house are supported by three rows of main posts. Beams made of bamboo, called "urpun,"

Figure. 2. Karbi house

Nocte Vernacular House

The distinctive vernacular style of the Nocte people, who are native to Arunachal Pradesh, Nagaland, and Assam, is shaped by their cultural heritage. Nocte buildings have palm leaves for the roof, bamboo for the walls, and wooden logs for the pillars. Raised on ladder-accessible platforms, distinct rooms fulfill various purposes, such as storage, cooking, and sleeping quarters. One-ear holders, major rafters, and common rafters make up the roof frame, while split bamboo and bamboo splinters are used to build the walls. "Louteyap" roof tiles are made by layering bamboo splinters between palm leaves. When building a Nocte house, you start by planting rows of support posts, build a platform out of bamboo that runs lengthwise and horizontally, and then concentrate on the roof frames. The unusual roofing technique is cutting palm leaves into tiles and fastening them.

Deori Vernacular House

A unique tribal community in Assam, the Deori people are part of the larger Bodo ethnicity. Traditionally built on stilts, deori houses are long and straight, composed of locally accessible materials such as wood, bamboo, thatch, and cane. Specific methods are used for the platform, roof, and walls, and the foundation is strongly supported by bamboo columns. Deori homes are divided into sections that may face different directions, all based on practical considerations. Planting platform posts, fastening bamboo in both horizontal and longitudinal orientations, and building walls with bamboo splints are all part of the construction process.

When building a Deori house, the platform with embedded posts must be built, attached, and bamboo that is both horizontal and longitudinal, followed by construction on the roof frame. The Deori people have certain taboos and customs around the building of houses and housewarming celebrations.

Figure. 3. Deori house

Sonowal Karachi House

Belonging to the larger Bodo clan, the Sonowal Kacharis are the third largest plain tribe in the state. They make up 18% of Majuli's population and have historical ties to other tribes. They don't speak a separate language; instead, they speak Assamese. Their residences are scattered throughout several areas and are built on high plinths composed of wood, bamboo, cane, reed, and thatch, mimicking Assamese architectural forms. The prefix "Sonowal" denotes their past involvement in gold-washing. Homesteads have tidy courtyards surrounded by bamboo fencing. Granaries follow the customs of the Bodo people.

Separate rooms, such as a public drawing room, are built inside homes.Building requires access to nearby resources. Site selection is dictated by customs such as "danda-chowa". Notable structures with distinct purposes are Bar-ghar, Maral-ghar, and Chora-ghar.

Moran Vernacular House

The areas of Tinsukia and Dibrugarh display a unique architectural style that is characteristic of the Moran tribe, who were the rulers of the Matak Kingdom historically. Built in the midst of thick vegetation, Moran dwellings have gable roofs and are earth-fast. These homes have different purlin numbers according to social status and are orientated either east-west or north-south. The main door's deliberate height, which reflects Moran customs of respect and readiness for fight, permits entry without bending. The main door's height has cultural significance, and Moran homes feature triangle fronts. The south-facing Chora-ghar has bamboo walls arranged vertically and is held up by purlins. The Dheki-chang is made to store bamboo objects. Bedrooms and kitchens are located in the Xoa-ghar, which is connected to Chora-ghar. The Moran people eat crouching, which is consistent with their alert demeanor.

Ikra Vernacular House

Narrow-leafed plant called ikra is an essential feature of traditional Assamese-style dwellings across the northeast. These houses, which are mostly for residential use, highlight inventiveness in the area by utilizing ikra's special features. Ikra homes are inexpensive, eco-friendly, and earthquake-resistant. These homes also have GI sheet roofs, bamboo-woven wooden frames, and walls made of stone or brick. Wooden or bamboo trusses hold up roofs. These buildings are earthquake-resistant. Functionality-based designs are different, meeting both home and business requirements. Different layouts are used for government buildings, churches, schools, and other spaces, with a focus on use and security.

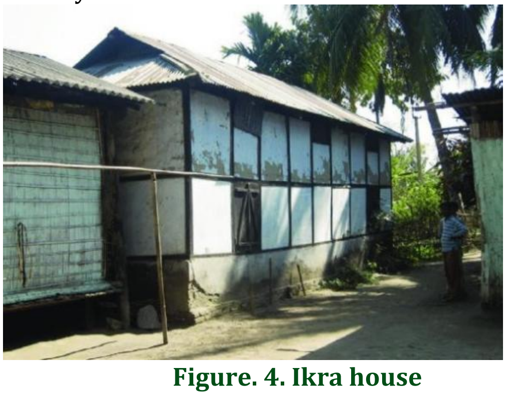

Figure. 4. Ikra house

Mishing vernacular House

The largest tribe of Majuli, the Misings, build their traditional stilt homes out of wood, bamboo, cane, and reed. Wild animal protection is provided by stilted platforms, which prioritize community above individual property. The raised platform has granaries to protect grain, sleeping rooms, and a front portico for hand loom activity. Ten levels make up mishing dwellings, which combine platform and superstructure layers. From tie-beams to thatched roofs, each layer has a distinct function. Clan-specific construction practices represent their history of migration. Separate partitions are discouraged by the open architecture, which emphasizes communal life. The ground floor is used for gatherings and rice husking, among other things.

Figure. 5. Mishing House

Contemporary Relevance of Assam Vernacular

Vernacular architecture in Assam, especially in the Brahmaputra valley, provides a practical and beautiful way to meet the housing needs of local communities. These buildings, classified into community, seasonal, and residential types, serve both practical and cultural purposes. The term "vernacular" reflects how this architecture is learned and passed down through oral tradition and imitation, much like learning language. Recognized globally for its affordability and cultural value, vernacular architecture is endorsed by experts like Watson, AIA, and Bertaud as a solution to global housing challenges. It also attracts tourists interested in eco-tourism, cultural experiences, and staying in local homes.

The Assamese government recognizes these benefits and has launched initiatives like "Aamaar Aalohi" to promote rural home-stays, creating jobs for educated youth in tourist areas. These programs allow visitors to explore remote regions, experience village life, and immerse themselves in local culture. Additionally, vernacular architecture supports businesses such as "dhabas" – hotels and restaurants designed like traditional pajaghars, using local materials to create an authentic ethnic atmosphere.

One notable example is Haflong's "Ethnic Village," showcasing vernacular styles from different ethnic communities. These applications preserve cultural heritage while boosting the local economy.

Figure. 6. View of house

CASE STUDY

Mishing House, Citaldubi

Traditional regions of mishing vernacular houses have a special value for studies on anthropology and architecture.is situated in a region with several disappearing home clusters and a significant number of those traditional homes nearby. People who migrate have a profound awareness of their natural surroundings.The utilization of vivid colors, beautifully woven bamboo walls, and stilted design shows artistic workmanship ingrained in the customs is demonstrated by their aesthetic appeal.Because the home faces north-west, wind may easily flow in all directions. The rooms i n the house are arranged in accordance with the beliefs of the Majli people and the significance of placement.Bamboo mats used for the walls and ceiling of the house provide excellent internal climate control, especially in tropical and humid climates.

Karbi house, Hamren

The house is situated in a Karbi village in Assam, nestled in a deserted and hilly area near the village access point but a bit distant from the main clusters.Surrounded by shrubs and uneven terrain, the building is elevated to match its surroundings. This typical Karbi house, representing one of Assam's vernacular house types, maintains its distinct identity with sufficient separation from the village. The adaptation of the house to its environment highlights its integration with the surroundings.

Table 1 : Parameters of Case study

SL.No	PARAMETERS	INFERENCES
1.	Zoning	➢ Mishing house has a central communal area at their core, serving as the hub for social activities. ➢ Sleeping quarters and private rooms is along house's periphery for privacy, while the kitchen area is situated to avoid interference with communal spaces.
2.	Circulation	➢ Circulation around the interior of Mishing house is be guided by the intricate woven bamboo walls, which create visual dividers within the space.
3.	Sustainibility Aspects	➢ Mishing house relys on natural materials, contributing to sustainability and preserving traditional building practices. ➢ This house emphasizes communal living, with shared resources and a sustainable lifestyle integrated into their cultural practices.
4.	➢ Landscaping	➢ The house has cultivated plots of land around their houses where they grow rice, vegetables, and other crops. ➢ These agricultural spaces reflect the agricultural lifestyle of the community. ➢ In addition to cultivated crops, the house also has fruit trees and other vegetation around.
5.	Socio-Economic considerations	➢ Mishing house is designed to accommodate the traditional livelihoods of the community, such as hand loom and fishing Mishing house influencing the choice of materials and design elements that are both affordable and sustainable for the community.
6.	Material	➢ Bamboo ➢ Thatch ➢ Wood ➢ Timber poles ➢ Bamboo weaved panels
7.	Construction	➢ Mishing house is built on stilts, providing protection against flooding in the Brahmaputra River basin. ➢ Bamboo is the primary construction material, used for the framework, walls, and roof. Thatched roofs are common.

Over time, the house has undergone various modifications, including additions and removals. The raised flooring, typical of Karbi houses with bamboo mats spaced to aid in cooling, helps regulate floor temperatures. The pitched roof, now covered with corrugated iron sheets, originally featured thatch until the 1980s, reflecting changes influenced by family circumstances and socio-economic conditions at the time. Bamboo-paneled walls plastered with mud contribute to maintaining cooler interior temperatures, crucial given the region's high humidity.

Table 2 : Parameters of Case study

SL.No	PARAMETERS	INFERENCES
1.	Zoning	➢ The Karbi traditional house is divided into two parts. ➢ There's the main house, Hem-pi, exclusively for family and close relatives, and another section called Hong-pharla for guests or those of higher status. These parts are connected by an open platform, Hong-jai.
2.	Circulation	➢ Karbi house has a central hearth, which serves as the focal point of the house. ➢ Circulation is designed to provide easy access to all parts of this central space.
3.	Sustainability Aspects	➢ Karbi house ois adapted to the hilly terrain of it's region, taking advantage of the local climate and available resources for sustainability. ➢ Generally, Karbi houses may use indigenous materials and traditional construction methods, emphasizing sustainability and reduced resource consumption.
5.	Landscaping	➢ The landscaping is minimal, allowing the natural beauty of the landscape, including the hills and forests, to serve as the backdrop for the house. ➢ Stone markers or simple fencing materials like bamboo defines the boundaries of the property and enhance the landscaping
6.	Socio-Economic considerations	➢ Karbi house incorporates design elements that support the economic activities of the community, such as agriculture and handicrafts etc. ➢ Economic factors affect the choice of building materials and construction techniques, often favoring locally sourced and cost-effective options. ➢ The economic aspects of Karbi houses are intertwined with cultural and social significance, reflecting the community's economic practices and identity
7.	Material	➢ Bamboo ➢ Thatch ➢ Wood ➢ Timber poles ➢ Bamboo weaved panels
8.	Construction	➢ Similar to Mishing houses, Karbi house also use bamboo and thatch. Bamboo is the primary structural element. ➢ The house is built on elevated platforms to safeguard against floods. ➢ Building the Karbi house is a community effort, with the involvement of family and community members. ➢ The foundation uses cement and concrete for better stability, same is true for the mishing house.

Figure.7. View of House

Modern Assam type house

The house exemplifies the traditional Assam type architecture with bamboo-panel walls and the use of local materials, surrounded by spacious open areas that capture the essence of regional design. Its sloped roof, a nod to traditional aesthetics, shelters a home that embodies both cultural heritage and sustainable living practices. Despite enduring minor earthquakes common in the region, the house has remained resilient, with minimal structural impact from these seismic activities. This house perfectly illustrates how vernacular architecture in the state has evolved over time. The bamboo railings have been periodically updated, and front elevations repainted and refurbished. Mosquito nets have been installed on balconies and open spaces to combat malaria during certain seasons, while ensuring adequate ventilation. Amidst its walls, a blend of history and modernity resonates, narrating tales of Assam's past while embracing a future where tradition and innovation harmoniously coexist.

Figure. 8. House view

CONCLUSION

Through the use of vernacular architecture, a community can foster relationships. It refers to the utilization of regional resources, methods, and sustainable practices while honoring the customs of the local community and preserving its traditions. Vernacular architecture has been less common in Assam over time, particularly in the state's urban areas. Because modern materials and processes are more readily available, they can be constructed quickly, and incorporating "modernism" into one's home is becoming increasingly important. The preservation of Assamese vernacular architecture's legacy element and remembering the influences, changes, and evolution of these techniques over time are crucial for the practice's future.

Because Assam is home to numerous distinct ethnic groups, each with its own unique characteristics, the state's vernacular customs vary depending on the numerous tribal cultures and societal influences that have shaped them. The widespread usage of brick and concrete around the world has led to a number of issues, including surface temperature rise and deforestation. These vernacular behaviors become increasingly important as these issues result in the depletion of resources. For the sake of both people and the environment, combining these contemporary approaches with more established ones can provide more beneficial and long-lasting outcomes.

SL.No	PARAMETERS	INFERENCES
1.	Zoning	➢ The house has an open verandah connecting indoor and outdoor spaces. ➢ The living area align along the central axis, and bedrooms offer privacy on one side. ➢ Kitchens and bathrooms are in separate sections.
2.	Circulation	➢ Assam type house features a spacious verandah or porch at the front, which serves as the main entry point. ➢ The circulation pattern takes into account the need for cross-ventilation, especially during Assam's hot and humid climate.
3.	Sustainibility Aspects	➢ This house uses locally sourced, sustainable materials to reduce environmental impact and promote the local economy. ➢ This houses is designed to adapt to the local climate, with features like elevated structures to mitigate flooding, promoting energy efficiency etc.
4.	➢ Landscaping	➢ The Assam type house features open courtyard, this area landscaped with small gardens, flowering plants, or decorative elements like sculptures, providing a visually appealing and functional space. ➢ Landscaping includes outdoor areas, which are used for social gatherings and relaxation
5.	Socio-Economic considerations	➢ Economic status often dictates the choice of construction materials. Local, cost-effective materials are favored to keep construction affordable.Like for this house, the use of local bamboo and then modern materials later on. ➢ The house is adapted to the local climate and lifestyle, focusing on providing comfort and efficiency while minimizing energy costs.
6.	Material	➢ Corrugated iron sheets ➢ Bricks ➢ Cement mortar ➢ Bamboo panels ➢ Timber panels ➢ Concrete foundation ➢ Iron poles ➢ Timber poles
7.	Construction	➢ The house has extensice use bamboo and concrete, providing insulation and are suitable for the local climate. ➢ Bamboo is used for the framework and walls. ➢ The design adapts to the humid and rainy climate, focusing on keeping the interior cool and dry. ➢ The new materials are being used like Concrete, brick etc. This house is an example of how new and old vernacular can be incorporated together.

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Effect of Thermal Comfort Through Building Shape and Orientation: A BIM-Based Analysis

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Abstract— Building shape and orientation play a crucial role in mitigating the impacts of climate change on thermal comfort within urban environments. This study investigates the thermal performance of three building shapes – square, rectangle, and L-shape – with identical floor areas and entrances facing south. Using Building Information Modeling (BIM) software Revit 2024, the analysis combines heating and cooling load calculations, system analysis tools, and Insight 360.

This study reveals that building orientation significantly impacts thermal comfort. Rotating a square building by 90° slightly increases thermal comfort, while 270° rotation slightly decreases it. The rectangular building exhibits optimal thermal comfort without rotation and experiences significant discomfort when rotated 270°. L-shaped buildings achieve maximum thermal comfort with a 180° rotation and minimum comfort with a 90° rotation. This variation is attributed to the amount of surface area facing the west, which receives the most sun exposure and creates thermal discomfort. The cooling loads in kWh and EUI for various Window-to-Wall Ratios (WWR) were also analyzed for each scenario. It was found that low WWR

This research suggests that careful consideration of building shape, orientation, and south-facing entrances during the design process can significantly enhance thermal comfort and contribute to climate-resilient urban planning. The findings provide valuable insights for architects, engineers, and urban planners to design sustainable and resilient buildings that adapt to the challenges of climate change.

Keywords: BIM; Building Shape; Thermal Comfort; WWR; Revit 2024

INTRODUCTION

Passive cooling design strategies are methods to reduce indoor overheating risk and cooling energy demand in buildings, especially in warm and humid tropical climates, where high temperatures and humidity levels pose serious challenges for thermal comfort and health (Gamero-Salinas et al., 2021).

Indoor overheating risk is the likelihood of indoor environments exceeding the thermal comfort limits for occupants, which can have negative impacts on health, productivity, and well-being. Indoor overheating risk can be assessed using different metrics, such as hours of exceedance, indoor overheating degree, or adaptive comfort models (Arsad et al., 2023).

Climate change is expected to increase the frequency and intensity of heat waves and extreme weather events, which will exacerbate the indoor overheating risk and the cooling energy demand in tropical regions. Therefore, building sector adaptation measures are urgently needed to cope with the current and future challenges posed by global warming (Attia et al., 2023).

Existing studies on passive cooling design strategies in tropical climates have focused on different aspects, such as natural ventilation, roof insulation, wall absorptance, window shading, semi-outdoor spaces, and vegetation. However, there is still a gap in the relative influence of these strategies on lowering the indoor overheating risk, as well as the extent to which they reduce the need for active cooling devices.

This paper aims to fill this gap by investigating the impact of passive cooling design strategies on the indoor overheating risk in three building shapes (Square, Rectangle and L-Shape) all having same building area. The paper emphasizes the importance of passive cooling and overheating protection design strategies using building shapes, orientation and WWR (Window-to-Wall Ratio). (Gamero-Salinas et al., 2021)

Location and Climate Scenarios

Three building shapes were chosen for analysis: a square shape, a rectangle shape, and an L-shape (see figure 1). The building models depicted in figure 1 were intended for construction at Mizoram University in Aizawl, Mizoram. This location experiences slightly more extreme weather conditions compared to other parts of Mizoram, but the weather is still moderate in comparison to other states in India. The weather data for Mizoram University, obtained from the Meteonorm software, is presented in figure 2. However, Mizoram University, being situated at a relatively low altitude from mean sea level, encounters slightly more severe weather conditions compared to other areas of Aizawl. The average temperature during summer ranges from 20°C to 29°C, while during winter it ranges from 11°C to 21°C. These temperatures are rather moderate compared to other regions in India. Due to the increasing impact of global warming, temperatures are expected to rise significantly.

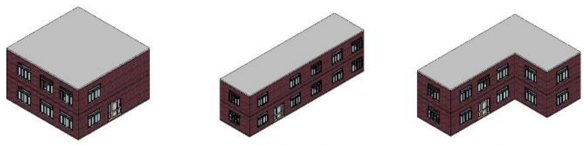

Figure 1: The Three main building shapes

Consequently, we have made the decision to develop cost-effective and efficient solutions to ensure thermal comfort. Thorough planning is crucial during the initial stages of building construction. In this study, we have undertaken research to enhance thermal comfort by taking into account factors such as building design, orientation, and window-to-wall ratio (WWR). (Hauzel et al., 2024)

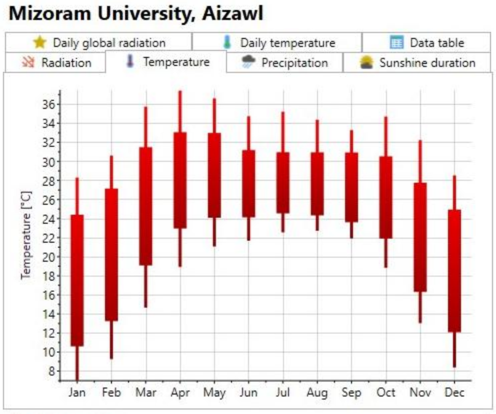

Figure 2: Weather data of Mizoram University generated by Meteonorm software

U-Values

U-value, also known as thermal transmittance, measures the rate of heat transfer through a building element (material or composite assembly) per unit area and temperature difference (Doors, 2023). It essentially quantifies how well an element resists heat flow, with lower U-values indicating better insulation and less heat loss or gain. U-values are typically expressed in watts per square meter per kelvin (W/m^2K) (Doors, 2023).

Since we are using BIM modeling for this study, understanding the thermal properties of building materials is important. In particular, U-values, or thermal transmittance values, play a critical role in assessing heat transfer through various building elements. Since our focus is on analyzing the impact of building shape, orientation, and window-to-wall ratio (WWR) on thermal performance, we have intentionally chosen common building materials without incorporating insulation. This deliberate selection allows us to isolate and observe the influence of these geometric and design factors on the thermal behavior of our BIM model.

The U-Values of the various building materials are given in Table 1. These U-Values are calculated using Vesma.com's Online U-Value Calculator (*Uvalue01.Xls*, n.d.)

Table 1. U-Values of various building elements

Building Element	Material	Thermal Conductivity (K-Value) W/m.K	Thickness (m)	U-Value $W/m^2.K$
Wall	Brick walls	0.33	0.1	3.34
Roof (Flat)	RCC roof	0.61	0.15	4.05
Window	Single Glazing	5.5473	0.005	1.05

LITERATURE REVIEW

In 2018, a study was undertaken to analyze the impact of building shape, zones, orientation, and window to wall ratio (WWR) on the lighting energy need and thermal comfort in naturally ventilated dwellings located in tropical regions. The study determined that a house with a rectangular shape and a centrally positioned staircase offers superior thermal comfort when the window-to-wall ratio (WWR) is set at 20. Regarding alternative Whole-Window Replacement (WWR) systems, it is worth noting that L-shaped variants offer superior thermal comfort when the staircase is located at either the shorter corner or the middle (Pathirana et al., 2019). A 2019 study utilized BIM simulation to find the ideal temperature range for naturally ventilated mosques, prioritizing thermal comfort. While such buildings are known for superior indoor air quality, the study acknowledged the difficulty in achieving consistent thermal comfort in these spaces (Sulistiawan, n.d.).

Recent research (2023) delves into the thermal behavior of building envelopes, encompassing roofs, walls, windows, and skylights. This comprehensive analysis extends beyond mere observation, offering practical recommendations for optimizing building performance. Specifically, the study suggests improvements in Heating, Ventilation, and Air Conditioning (HVAC) set points, cooling and heating efficiency, airflow rates, and ventilation strategies. By addressing these areas, buildings can achieve improved thermal comfort and potentially reduce energy consumption (Habibi, 2023). Another paper presents a holistic review of the data and information needed for the integration of BIM with thermal comfort modeling for commercial office spaces. Thermal comfort is dependent on multiple factors such as indoor environmental conditions, user behavior, properties of building materials, etc (Alshehri et al., n.d.). However, for this study, only building shapes, orientations and WWR will be considered

MATERIALS AND METHODS

This chapter outlines the materials and methods employed in this study to investigate the impact of building shape and orientation on thermal comfort. Our research utilized Revit 2024, a Building Information Modeling (BIM) software, for both model creation and thermal analysis.

Building Models And Orientations

Three distinct building shapes of equal floor areas were examined: square, rectangular, and L-shaped each being G+1. Initially, all buildings were south facing, i.e. they had their entrances doors at the south side of the building. Each shape was rotated clockwise in four cardinal orientations: 0° (north), 90° (east), 180° (south), and 270° (west). This allowed us to capture the influence of sun exposure and solar heat gain on thermal comfort across different geometries. The rotation of each building shape is shown in figure 3, 4 and 5.

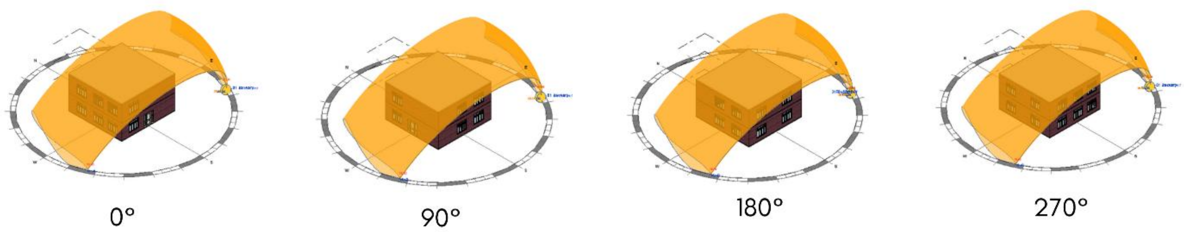

Figure 3: Rotation of a Square Building

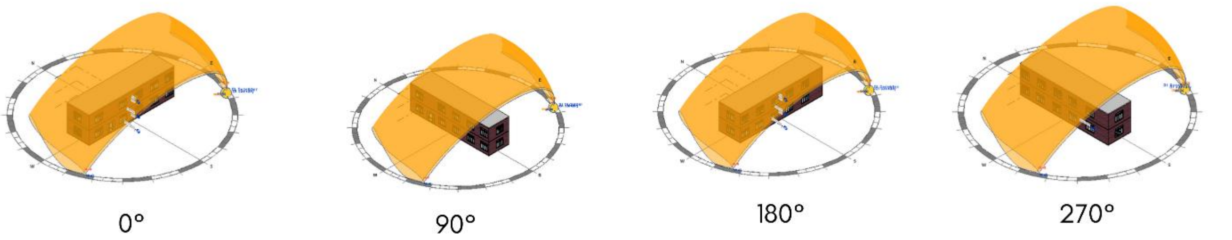

Figure 4: Rotation of Rectangular Building

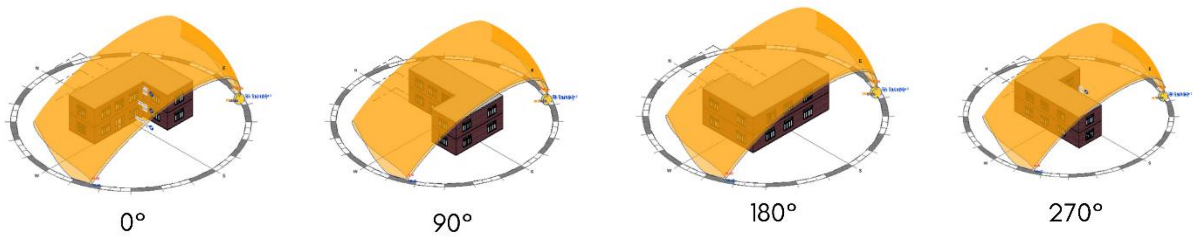

Figure 5: Rotation of L-Shaped Building

Thermal Analysis using Revit

Revit's built-in Heating and Cooling Loads Calculation engine served as the primary tool for thermal analysis. This engine utilizes weather data, building materials, and internal heat gains to estimate heating and cooling requirements for maintaining thermal comfort within the simulated spaces. For each model and orientation, we ran simulations to generate heating and cooling load data, considering a one-year period, providing insights into the thermal performance of each configuration.

Insight 360 and WWR Analysis

While Insight 360 offers a comprehensive suite of analytics for building operations, we employed its Window-to-Wall Ratio (WWR) analysis capabilities in this research. WWR plays a crucial role in controlling sunlight penetration and heat gain, impacting thermal comfort. Insight 360 provided detailed reports on WWR for each model and orientation, allowing us to analyze the relationship between this design parameter and thermal performance. It uses a scale called EUI (Energy Use Intensity) for measuring thermal comfort. EUI is a key metric used in the field of building energy efficiency. It is defined as the annual energy consumption of a building relative to its gross square footage (*Energy Use Intensity (EUI) - AIA KnowledgeNet*, n.d.).

Data Collection and Analysis Techniques

The heating and cooling load data and WWR reports generated from Revit and Insight 360 formed the primary data sets for this study. These data points were compiled and analyzed using statistical tools to identify trends and relationships between building shape, orientation, WWR, and thermal comfort metrics. The specific metrics employed will be discussed in greater detail in the Results and Discussion section.

RESULTS AND DISCUSSIONS

Heating and Cooling Load Data

This section presents the results of the heating and cooling load calculations for the three main building shapes (square, rectangle, and L-shape), each rotated in four different orientations (0°, 90°, 180°, and 270°). The primary metric for judgment was the ‘Peak Cooling Total Load’, although the ‘Peak Heating Load’ was also considered. The following heating and cooling loads data was observed for all building shapes and orientations (Table 2):

Table 2: Heating and Cooling Load Results

BUILDING SHAPE	ORIENTATION	PEAK COOLING TOTAL LOAD (W)	PEAK HEATING LOAD (W)
Square	0°	53085	18092
	90°	47853	18092
	180°	50361	18092
	270°	50401	18092
Rectangle	0°	47893	24399
	90°	59329	24399
	180°	48189	24399
	270°	59554	24399
L-Shape	0°	47685	24073
	90°	53040	24073
	180°	47754	24073
	270°	52044	24073

We will discuss the results by looking into each building shape in the next section.

Square

For the square shaped building, the peak cooling total load is highest at no rotation (0°) when the entrance faces south and the peak cooling total load is lowest at 90° rotation when the entrance faces west.

Rectangle

For the rectangle shaped building, the peak cooling total load is highest at 270° and also in 90° rotation when the entrance faces east and west respectively and the peak cooling total load is lowest at 0° and 180° rotation when the entrance faces south and north respectively.

L-Shape

For the L-shaped building, the peak cooling total load is highest at 90° when the entrance faces west and the peak cooling total load is lowest at 0° and 180° rotation when the entrance faces south and north respectively.

WWR Analysis

This section presents the results of the Window-to-Wall Ratio (WWR) analysis for three main building shapes (square, rectangle, and L-shape), each rotated in four different orientations (0°, 90°, 180°, and 270°). The primary metric for judgment was the Energy Use Intensity (EUI), measured in kWh/m^2/yr.

It is important to note that increasing the WWR increases the EUI, indicating a higher energy consumption. However, decreasing the WWR too much can decrease the air change per hour, which can affect the indoor air quality, natural lighting, and potentially the thermal comfort of the occupants.

Table 3: Window-to-Wall Ratios and Energy Use Intensities of each building shape, orientation and face

BUILDING SHAPE	ORIENTATION	SOUTHERN WWR (%)	EUI	NORTHERN WWR (%)	EUI	WESTERN WWR (%)	EUI	EASTERN WWR (%)	EUI
Square	0°	16	-1.08	19	-1.45	28	-8.63	19	-4.07
	90°	19	-5.58	28	-2.25	16	-0.63	19	-4.18
	180°	19	-5.82	16	0.08	19	-5.65	28	-6.32
	270°	28	-8.62	19	-1.45	19	-5.63	16	-0.64
Rectangle	0°	27	-0.52	24	-0.11	19	-0.11	19	-0.08

	90°	19	-0.11	19	-0.02	27	-0.48	24	-0.43
	180°	24	-0.58	27	-0.08	19	-0.11	19	-0.08
	270°	19	-0.11	19	-0.02	24	-0.55	27	-0.38
L-Shape	0°	27	-6.87	19	-1.87	19	-4.96	19	-3.95
	90°	19	-3.97	19	-1.52	26	-6.85	19	-5.86
	180°	19	-5.86	26	-1.88	19	-4.70	19	-3.93
	270°	19	-3.95	19	-1.34	19	-7.04	26	-5.96

Square Shaped Building

- **0° rotation**: The southern walls had the highest EUI at a WWR of 16%, while the western walls had the lowest EUI at a WWR of 28%.
- **90° rotation**: The western walls had the highest EUI at a WWR of 16%, while the southern walls had the lowest EUI at a WWR of 19%.
- **180° rotation**: The northern walls had the highest EUI at a WWR of 16%, while the eastern walls had the lowest EUI at a WWR of 28%.
- **270° rotation**: The eastern walls had the highest EUI at a WWR of 16%, while the southern walls had the lowest EUI at a WWR of 28%.
- **Rectangle Shaped Building**
- **0° rotation:** The eastern walls had the highest EUI at a WWR of 19%, while the southern walls had the lowest EUI at a WWR of 27%.
- **90° rotation:** The northern walls had the highest EUI at a WWR of 19%, while the western walls had the lowest EUI at a WWR of 27%.
- **180° rotation:** The eastern walls had the highest EUI at a WWR of 19%, while the southern walls had the lowest EUI at a WWR of 24%.
- **270° rotation:** The northern walls had the highest EUI at a WWR of 19%, while the eastern walls had the lowest EUI at a WWR of 27%.
- **L-Shaped Building**
- **0° rotation:** The northern walls had the highest EUI at a WWR of 19%, while the southern walls had the lowest EUI at a WWR of 27%.
- **90° rotation:** The northern walls had the highest EUI at a WWR of 19%, while the western walls had the lowest EUI at a WWR of 26%.
- **180° rotation:** The western walls had the highest EUI at a WWR of 26%, while the northern walls had the lowest EUI at a WWR of 19%.
- **270° rotation:** The northern walls had the highest EUI at a WWR of 19%, while the western walls had the lowest EUI at a WWR of 19%.

CONCLUSIONS

This study explored the impact of building shape and orientation on thermal performance through computational analyses. Our findings highlight the interplay between window-to-wall ratio (WWR) and wall surface area in influencing heat gain and energy use intensity (EUI).

For the square shape with uniform side lengths, WWR emerged as the dominant factor. When high-WWR walls faced east or west, they received substantial solar radiation, leading to significant cooling loads and consequently, higher EUI values.

In contrast, the rectangular shape, with two longer sides, revealed wall surface area as the more critical factor. East or west-facing walls with larger surface areas experienced increased solar heat gain, resulting in higher cooling loads and EUI.

And finally, in the case the L-shaped building, both the wall surface area and the WWR play an important role in the solar heat gain.

These observations underscore that the primary determinant of heat ingress varies depending on the building's geometry and orientation. Further research could investigate the combined effects of shape, orientation, WWR, and other design parameters on energy performance across diverse climatic zones.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Sustainable Utopias: A Comprehensive Exploration of Eco-Village Planning for the Indian Context

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Abstract—In the Indian context, eco-village planning is a potent approach aiming to balance all the significant sustainability factors for a developing economy. It addresses the interrelated issues of climate resilience, environmental preservation, and rural development through a holistic lens. Since long, the Indian government has been promoting sustainable development through various initiatives, and Eco-Village aligns with these goals and provides a framework for implementing eco-friendly practices at the grassroots level. Therefore, this paper delves into the intricate realm of eco-village planning, amalgamating a rich tapestry of literature, case studies, and key planning factors. With a specific focus on the Indian context, the research aims to identify and analyse the multifaceted components integral to the creation of eco-villages. The paper aspires to provide a holistic understanding of the challenges and opportunities inherent in the planning process by investigating successful case studies in the national and international context and synthesizing existing knowledge. Furthermore, the study proposes a visionary way forward, delineating a roadmap for designing and implementing an ideal eco-village in India.

Keywords: Sustainability; Green Architecture; Community Development; Permaculture; Biodiversity

INTRODUCTION

With its diverse landscapes, cultural diversity, and complex socio-economic fabric, India is at a critical juncture in pursuing sustainable development. Confronting challenges posed by climate change, environmental degradation, and the need for inclusive rural growth, the demand for innovative and comprehensive solutions is more apparent than ever. In response to these challenges, eco-village planning has emerged as a compelling approach. It offers a holistic strategy to address the intricate interplay between environmental preservation, community development, and economic sustainability.

The concept of eco-village planning is vital in harmonizing environmental stewardship with developmental ambitions in a rapidly developing country. As India navigates the dual challenge of meeting the needs of a growing population while safeguarding its ecological heritage, eco-village planning stands out as a viable pathway. It promotes self-sustaining communities that mitigate environmental impacts and foster social inclusivity and economic resilience. The alignment of eco-village principles with the broader sustainable development goals of the Indian government further underscores its significance as a pragmatic and integrative solution (Du Pisani, 2006).

This study aims to thoroughly investigate eco-village planning within the Indian context, focusing on identifying its complexities, opportunities, and obstacles. Key components contributing to the success of eco-village projects will be explored in sections 2 and 3, drawing insights from existing literature, case studies, and theoretical frameworks. Sections 4 and 5 will explore the challenges and opportunities inherent in planning and implementing eco-villages, understanding the factors influencing their success. Section 6 will propose a visionary roadmap for designing and implementing an ideal eco-village in India, considering the nation's socio-cultural diversity and unique environmental characteristics.

This research seeks to contribute to the ongoing discourse on sustainable development in India by addressing these objectives. It aims to offer valuable insights that can inform policy decisions, guide planners, and empower communities to pursue eco-friendly and resilient futures.

LITERATURE REVIEW

In synthesizing the evolution, global trends, relevance in the Indian context, and critical components of eco-village planning, this literature review establishes a foundation for the subsequent analysis and exploration of eco-village planning in the Indian context.

Evolution of eco-village concept

The evolution of the eco-village concept started in the late 20th century when a growing awareness of environmental issues prompted a shift in paradigms towards sustainable living (Du Pisani, 2006; Koduvayur Venkitaraman, 2022). The concept gained traction as communities sought alternatives to conventional urban and rural development models, embracing principles of ecological balance, community engagement, and self-sufficiency. These ideas, termed "experimental utopias, " aimed to strive for a different approach towards community-level place-making similar to early 20th-century urban architectural concepts. The principle of experimentation offers vital insights into the village's process of reforms and evolves the sustainability vision. Eco-villages have collective identities that enable them to put their goals into action, thanks to shared values and interpersonal connections. Early experiments, such as the Findhorn Eco-village in Scotland and the Auroville community in India, laid the foundation. for the global eco-village movement by exemplifying holistic living practices, homogeneous cultural identity and emphasizing a symbiotic relationship with nature.

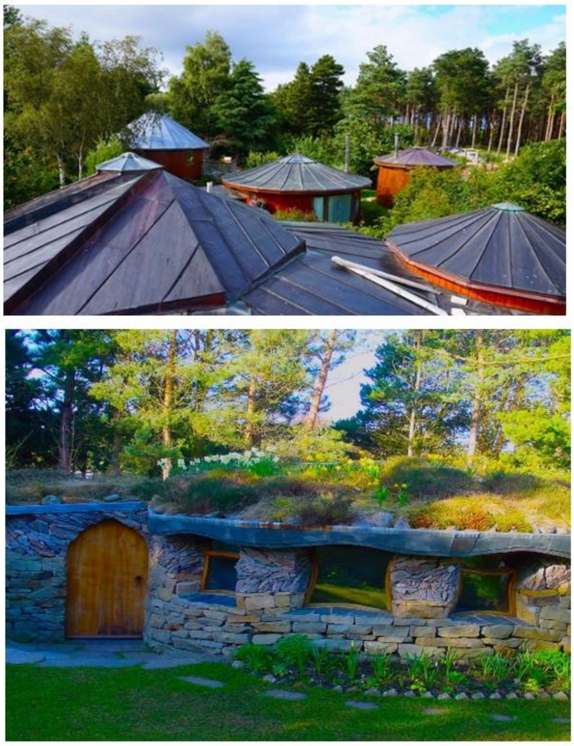

Figure 1: Findhorn Ecovillage.

Global trends in eco-village planning

Across the globe, eco-village planning has evolved into a dynamic and diverse field, reflecting regional nuances while adhering to common sustainability principles. Noteworthy trends include integrating renewable energy systems, waste reduction strategies, and implementing permaculture principles (Arena and Faake, 2015). The term "Permaculture" was introduced by Bill Mollison and David Holmgren in the 1970s to refer to a comprehensive and dynamic system of perennial or self-sustaining plant and animal species that serve human needs. Communities such as the Crystal Waters Permaculture Village in Australia and the Sieben Linden Eco-village in Germany serve as benchmarks, showcasing innovative approaches to sustainable living and community governance. The global discourse on eco-village planning reveals a rich tapestry of experiences, lessons, and challenges that inform the contextualization of these models in diverse socio-cultural settings.

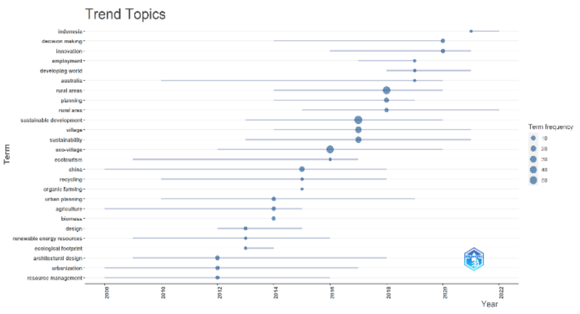

Figure 2: Results of Trends observed.

Relevance of eco-villages in the indian socio-economic landscape

The relevance of eco-villages in the Indian context is underscored by the country's unique blend of traditional wisdom, diverse ecosystems, and the imperative for sustainable development. With a significant proportion of the population residing in rural areas, adopting eco-village planning aligns with decentralized development and environmental preservation goals. Notable Indian examples, such as the Auroville in Tamil Nadu, The Dharnai Solar Micro-Grid project in Bihar and the Chirag in Himachal Pradesh, exemplify the successful integration of eco-friendly practices into the Indian socio-economic landscape, offering valuable insights into the adaptability and scalability of eco-village models (Sharma, 2020; Kumar, 2023).

Key components of sustainable community living

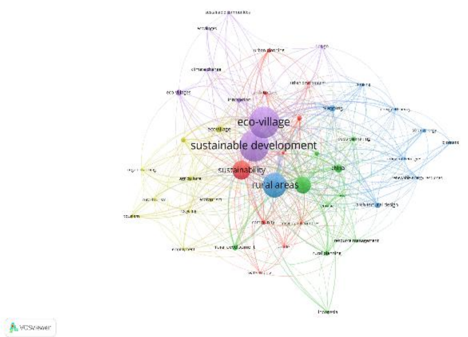

Figure 3: Results of Co-occurrence Analysis.

Eco-villages' success hinges on integrating key components that foster sustainable community living. These components include but are not limited to ecological design, renewable energy systems, waste management strategies, permaculture principles, and community governance structures. Studies on existing eco-villages emphasize the importance of a holistic approach considering environmental and social dimensions. The Bhutanese concept of Gross

National Happiness, which prioritizes holistic well-being over purely economic metrics, provides an insightful framework for understanding the interconnectedness of these components in fostering thriving and sustainable communities.

METHODOLOGY

An extensive literature review uncovered the evolution of the eco-village concept, global trends in eco-village planning, and their applicability within the socio-economic context of India. Systematically, scholarly databases, peer-reviewed journals, books, and reputable publications were investigated. The review process involved critical analysis, synthesis, and categorization of the gathered information to understand the subject matter comprehensively. This study was based on Qualitative Content Analysis (QCA) and focused on a systematic literature review of eco-villages to identify some critical parameters in the Indian context. QCA is a systematic research method for analyzing textual data to identify themes, parameters, and meanings within the content. The main reason for choosing QCA for the study is to provide a better and more comprehensive understanding of the results of various studies related to eco-villages worldwide. The study utilizes the SCOPUS database from 1993 to 2024. The search string ("Eco-village" OR "Sustainable Village") includes a wide range of documents related to eco-village or sustainable villages. A total of 274 documents were identified. After applying various stages of filtration, 230 documents (134 articles, 63 conference papers, 29 book chapters, and four review articles) were extracted, of which seven duplicates were removed.

For the QCA, 12 documents were selected after reviewing the title, abstract, and full text.

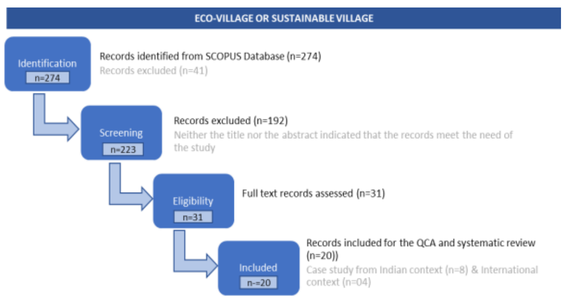

Figure 4: PRISMA flow diagram of systematic literature search and extraction of data/studies for review.

In addition, to complement theoretical insights with practical examples, we analyzed successful eco-village case studies nationally and internationally. This analysis focused on diverse geographical, cultural, and environmental contexts. By cross-referencing insights from the literature review with findings from the case study analysis, we identified commonalities, differences, and emerging trends. These findings were based on key planning factors crucial for creating sustainable eco-villages.

The following is a comprehensive introduction to the selected case studies, offering valuable insights into diverse approaches to sustainability within both Indian and international contexts.

Auroville, located in Tamil Nadu, India, is a unique experimental township founded in 1968 to embody human unity and sustainable living. The site planning and landscape integration in Auroville are deeply influenced by its sustainability principles, community living, and harmony with nature. Auroville's planning integrates various aspects of sustainable living, including architecture, landscaping, energy, waste management, and water conservation.

CASE STUDY

Eco-village planning factors analysis

Indian and international case studies are analysed, focusing on the planning factors of site selection and landscape integration, architecture and sustainable design, water management and conservation, renewable energy integration, waste management strategies, community engagement and social cohesion, and economic viability and livelihoods.

Site selection and landscape integration

Auroville's site selection embodies principles of harmony with nature, situated amidst the lush greenery of Tamil Nadu. The community integrates seamlessly with the landscape, preserving biodiversity and leveraging natural features for sustainable development.

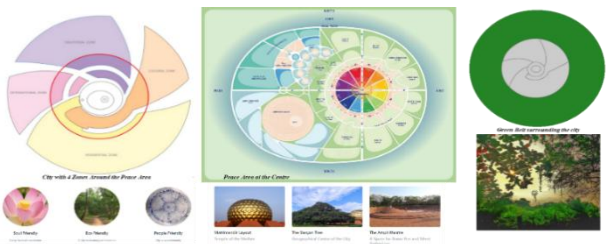

Figure. 5: City Layout of Auroville and a city in Harmony with Nature

Navadarshanam, situated in the Western Ghats of Karnataka, is nestled amidst lush forests and biodiverse landscapes. The community has carefully integrated its infrastructure with the natural terrain, preserving ecological corridors and biodiversity hotspots. Findhorn Eco-village in the Scottish Highlands demonstrates a harmonious integration with its natural surroundings, incorporating green spaces, organic gardens, and wildlife habitats within the community design (Copeland et al., 2023).

Architecture and sustainable design

Auroville's architecture emphasizes earth-friendly construction techniques such as rammed earth and sustainable materials, blending modern innovation with traditional wisdom. Buildings are designed to maximize natural ventilation and minimize energy consumption, reflecting a commitment to ecological sustainability (Venkitaraman & Joshi, 2022).

Figure. 6: Roofing Techniques in Auroville

Navadarshanam employs vernacular architecture and sustainable building techniques, utilizing locally sourced materials and passive design strategies to optimize thermal comfort and energy efficiency.

Findhorn Eco-village, Scotland, features eco-friendly buildings constructed from sustainable materials, utilizing passive solar design, natural ventilation, and renewable energy systems to minimize environmental impact and enhance energy efficiency (East, 2018).

Water management and conservation

Auroville employs innovative water management strategies, including rainwater harvesting, groundwater recharge, and wastewater recycling. Ponds and percolation pits help replenish groundwater levels, ensuring water security for the community while minimizing reliance on external sources.

In Navadarshanam, Karnataka, the community implements rainwater harvesting systems, permaculture practices, and watershed management techniques to replenish groundwater levels and ensure water self-sufficiency even during dry seasons.

Renewable energy integration

The Dharnai Solar Micro-Grid project, Bihar, exemplifies the successful integration of renewable energy into rural communities. By harnessing solar power, Dharnai has achieved energy independence, providing reliable electricity access to its residents while reducing carbon emissions and reliance on fossil fuels.

Figure 7: Installation of Solar Panels in Dharnai, Bihar

Barefoot College in Rajasthan, renowned for its pioneering efforts in promoting solar energy solutions in rural areas. Through its Solar Mamas program, the college trains women from marginalized communities to become solar engineers, empowering them to install and maintain solar electrification systems in their villages.

Community engagement and social cohesion

Adarsh Gaon Yojana, Maharashtra, fosters community participation and social cohesion through participatory planning and decentralized decision-making. By empowering residents to take ownership of development initiatives, Adarsh Gaon Yojana strengthens social bonds and promotes collective action for sustainable development.

Hiware Bazar, a village in Maharashtra, achieved remarkable social transformation through community-led initiatives focused on water conservation, afforestation, and sustainable agriculture. Decentralized governance structures and participatory decision-making processes have strengthened social bonds and fostered collective action for development.

Findhorn Eco-village, Scotland, fosters a vibrant community ethos through collaborative decision-making processes, communal facilities, and shared resources. Residents actively participate in ecological stewardship and social initiatives, fostering a sense of belonging and collective responsibility.

Economic viability and livelihoods

Adarsh Gaon Yojana, Maharashtra project prioritizes economic viability and livelihoods by promoting income-generating activities such as organic farming, agro-tourism, and handicraft production. By diversifying sources of income and creating employment opportunities, Adarsh Gaon Yojana enhances economic resilience and fosters sustainable livelihoods for rural communities.

Sieben Linden Eco-village, Germany, supports diverse livelihood opportunities through organic farming, eco-tourism, artisanal crafts, and renewable energy enterprises. The community emphasizes economic resilience and local self-reliance, fostering a thriving local economy while reducing dependence on external resources.

Waste management strategies

Chirag, Himachal Pradesh, implements innovative waste management strategies, including composting, recycling, and decentralized waste processing facilities. By minimizing waste generation and promoting resource recovery, Chirag contributes to environmental conservation and mitigates pollution impacts on local ecosystems.

Earthship Biotecture, New Mexico, USA, exemplifies innovative approaches to waste management, utilizing recycled materials such as tyres, bottles, and cans in construction. The design incorporates greywater recycling systems, composting toilets, and onsite food production to minimize waste generation and promote resource efficiency.

Lessons learned from the best practices

Across the various case studies analyzed, several common themes and best practices emerge:

Holistic Site Selection: All case studies prioritize integration with natural landscapes, preserving biodiversity and maximizing ecological benefits.

Innovative Architecture: Sustainable design principles are evident, with a focus on energy efficiency, passive cooling/heating, and the use of local materials.

Water Conservation: Rainwater harvesting, recharge, and wastewater recycling are integral to water management strategies, ensuring sustainable water access.

Renewable Energy Integration: Projects like Dharnai showcase the potential for renewable energy to enhance energy security and reduce environmental impacts.

Community Engagement: Active community participation and decentralized decision-making processes foster social cohesion and ownership of development initiatives.

Economic Viability: Income-generating activities and livelihood opportunities are essential for ensuring the economic sustainability of eco-village projects.

Waste Management: Innovative waste management practices contribute to environmental sustainability by minimizing pollution and promoting resource efficiency.

Through the analysis of these diverse case studies, it becomes evident that successful eco-village projects integrate a combination of innovative planning strategies tailored to their specific socio-environmental contexts. By prioritizing sustainability principles and holistic development approaches, these communities are inspiring examples of how integrated planning factors can contribute to creating resilient, self-sufficient, and vibrant living environments in India and internationally.

CONCLUSION

In conclusion, this paper has delved into the intricate realm of eco-village planning, focusing specifically on its relevance, challenges, opportunities, and best practices within the Indian context. Through a comprehensive literature review, analysis of case studies, and synthesis of crucial planning factors, several insights have emerged regarding eco-villages' potential to contribute to sustainable development in India.

Eco-village planning presents a potent approach to addressing the complex challenges of climate resilience, environmental preservation, and rural development. By integrating principles of ecological balance, community engagement, and economic sustainability, eco-villages offer a holistic strategy for harmonizing environmental stewardship with developmental ambitions.

The analysis of case studies in India and internationally has revealed a rich tapestry of experiences, lessons, and challenges that inform the contextualization of eco-village models in diverse socio-cultural settings. From Auroville in Tamil Nadu to Hiware Bazar in Maharashtra, from Findhorn Eco-village in Scotland to Earthship Biotecture in the USA, each case study highlights innovative approaches to site selection, architecture, water management, renewable energy integration, community engagement, economic viability, and waste management.

Across these diverse examples, several common themes and best practices have emerged, including holistic site selection, innovative architecture, water conservation, renewable energy integration, community engagement, economic viability, and waste management. These themes underscore integrating environmental, social, and economic considerations in eco-village planning to foster resilient, self-sufficient, and vibrant living environments.

It is imperative to translate these insights into actionable strategies for designing and implementing eco-villages in India which requires collaboration among policymakers, planners, researchers, and local communities to develop context-specific solutions prioritizing sustainability, inclusivity, and resilience.

In conclusion, eco-village planning offers a promising pathway towards balancing environmental preservation, community development, and economic sustainability in the Indian context. Through continued research, policy support, and community engagement, eco-villages have the potential to catalyse transformative change and contribute to a more sustainable and resilient India.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Green Building: A Universal Remedy for the Sustainable Built Environment in a Tropical Climate

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Abstract— In the current era, the issue of global warming is growing rapidly, A green building and climate-responsive architecture is getting more importance from the periphery to majority architecture. The necessity for green building is normally recognized by specialized in built environment and there have been a lot of efforts by progressive experts regarding the end result of global warming and the need of adaptation of Sustainability practices. Also, the tropical environment is faced with several harmful climatic impacts as a end result of high radiation received from the Sun. The effect is particularly felt in the region of human thermal comfort and the environment at large. The extensive changes of climate in tropical region, witnessed more or less the whole time of the year, leads to high rate of energy utilization for achieving thermal comfort inside the building by cooling the building as well as the surrounding atmosphere. This paper presents green buildings as a way to sustain the built environment in tropical region via lessening in cooling loads within structure interiors also the use of landscape basics to augment and diminish significantly the climatic impacts in new to attain the utmost sustainable built environment.

Keywords: Green Buildings, Sustainable, climate, responsive, built environment

INTRODUCTION

The natural environment functions as a living organism, just like the built environment. People interact with it, and it interacts with people. Urban environments serve as a reflection of our identities; observing our cities allows us to glimpse into our future. Housing is universally recognized as a fundamental human need, following only food and clothing. Housing, in all its aspects, is more than just a shelter as it encompasses all the social services and utilities that contribute to a livable community or neighborhood. It represents the complete environment in which individuals reside and develop. The pursuit of enhanced comfort and financial independence, the densification of crowded urban areas, the rise in traffic congestion, and the increasing problem of electric smog due to new communication technologies all contribute to escalating stress levels in individuals and society as a whole. These human activities lead to various environmental issues such as air and water pollution, the generation of domestic and industrial waste, the emergence of slums, and global warming, all of which have adverse effects on the quality of life and health standards of the population. The green building movement in the United States of America emerged from the necessity for more energy-efficient and environmentally friendly construction practices. There are multiple reasons for adopting green building practices, including environmental, economic, and social advantages. However, contemporary sustainability efforts call for an integrated and harmonious design approach for both new construction and the renovation of existing structures. Referred to as sustainable design, this method combines the building life-cycle with each green practice employed, aiming to create synergy among the practices utilized. This is energy-conscious design or energy-efficient design.

Green building, also referred to as green construction or sustainable building, involves the creation of structures and the implementation of processes that prioritize environmental responsibility and resource efficiency throughout the entire life cycle of a building. This approach encompasses various stages, including siting, design, construction, operation, maintenance, renovation, and deconstruction. By incorporating green building practices, traditional concerns such as economy, utility, durability, and comfort are expanded upon and complemented (U.S. Environmental Protection Agency, 2009).

One of the key aspects of green building is the utilization of renewable resources. This can be achieved through techniques such as passive solar, active solar, and voltaic methods, which harness sunlight. Additionally, the use of plants and trees helps to reduce rainwater run-off. Other techniques, such as the use of packed gravel or permeable concrete instead of conventional concrete or asphalt, contribute to the replenishment of groundwater. It is important to note that the specific practices and technologies employed in green building may vary across different regions, as they are constantly evolving (U.S. Environmental Protection Agency, 2009). However, there are fundamental principles that remain consistent and form the basis of this approach. These principles include efficiency in siting and structure design, energy and water efficiency, materials efficiency, enhancement of indoor environmental quality, optimization of operations and maintenance, and reduction of toxic waste. The essence of green building lies in the optimization of one or more of these principles. Furthermore, when green building technologies are synergistically designed, they can work together to produce a greater cumulative effect.

- Green buildings aim to minimize the impact of the built environment on human health and the natural environment by efficiently using resources such as energy and water.

- They also prioritize occupant health and productivity, while striving to reduce waste, pollution, and environmental degradation.

- Green housing is the foundation of sustainable living, with homeowners' lifestyle choices, house design, and functionality playing a crucial role in achieving green housing goals. This can be achieved through various measures such as energy reduction, alternative energy solutions, water conservation, eco-friendly location selection, use of green building materials, and promoting recycling.

Benefits of Green Building

Green building practices are focused on minimizing the environmental impact of new constructions. Buildings consume a significant amount of land, energy, and water, while also contributing to environmental changes. It is essential to reduce the consumption of natural resources and pollution emitted by buildings for long-term sustainability. The advantages of green housing can be divided into environmental and economic benefits. Environmental benefits include enhancing air and water quality, preserving biodiversity, ecosystems, and conserving natural resources like natural gas and fossil fuels. Economic benefits involve lower energy usage through energy-efficient appliances, lighting, home designs, and locations, as well as green energy solutions like solar panels and wind turbines. Green housing also adds value to properties. Green buildings can help in enhancing indoor air quality by reducing volatile organic compounds and other air pollutants. Selecting construction materials and interior finishes with low or zero emissions can improve indoor air quality and promote the health and productivity of occupants.

Traditional buildings often neglect energy and water conservation efforts, whereas green buildings prioritize these aspects. Green buildings incorporate various measures to increase energy efficiency, such as using high-efficiency windows and insulation in walls, ceilings, and floors. Passive solar building design is also commonly implemented in low-energy homes. By controlling personal temperature and airflow through the HVAC system and ensuring a well-designed building envelope, the thermal quality of a building can be enhanced. Additionally, strategic placement of windows, walls, awnings, porches, and trees can provide shade during the wet season and maximize solar gain during the dry season. Effective window placement can also maximize natural light, reducing the need for electric lighting during the day. Solar water heating is another method to reduce energy loads. Furthermore, integrating natural and artificial light sources can create a high-performance luminous environment, improving the lighting quality of a structure.

Figure1: Four Dimensions of Sustainable Development

Reference: https://repositories.lib.utexas.edu/server/api/core/bitstreams/3a0e3262-9727-4cda-ad4f-feea615ace53/content

Green architecture also focuses on waste reduction during construction and occupancy. Construction waste can be minimized by reducing the amount of material sent to landfills. Well-designed buildings also provide on-site solutions, such as compost bins, to reduce waste generated by occupants. To minimize the impact on water sources, options like using wastewater for subsurface irrigation or non-potable purposes (after treatment) and collecting rainwater are available.

Unlike conventional buildings, green buildings prioritize energy and water conservation, waste reduction, and the protection of ecosystems and resources.

Economic Performance

Conventional buildings have failed to provide the financial benefits that green buildings offer. These benefits encompass reduced operating costs through lower energy and water expenses, as well as decreased costs for waste disposal, environmental impact, and greenhouse gas emissions. Additionally, green buildings require less maintenance and replacement costs due to the superior durability of their materials.

Protection of Public Health and Enhanced Productivity

Indoor environments play a significant role in people's lives, as they spend approximately 90% of their time indoors. Unfortunately, indoor spaces often have higher pollutant concentrations compared to the outdoors, sometimes even up to 10 or 100 times higher (US, EPA, 2003). By adopting an integrated approach to constructing environmentally friendly and resource-efficient buildings, sustainable buildings offer tangible benefits to public health and productivity.

These "green" features, such as enhanced daylighting, natural ventilation, improved seating, and better indoor air quality, have been proven to enhance worker and student productivity while reducing absenteeism and illness. A study conducted at Herman Miller revealed a remarkable 7% increase in worker productivity after transitioning to a green facility with ample daylight. Similarly, the Heschong-Mahone group conducted a study in three cities, which demonstrated that students in classrooms with abundant daylight performed up to 20% better than those in classrooms lacking natural light.

Sustainable Landscaping Practices

Sustainable landscaping practices in tropical countries aim to create visually appealing landscapes that are in harmony with the local climate and environment. By minimizing the use of resources such as fertilizers, pesticides, and water, sustainable landscaping designs are not only cost-efficient but also environmentally friendly. Key components of sustainable landscaping include proper design, efficient irrigation, integrated pest management, and the use of native plants. These practices help preserve limited resources, reduce waste, and prevent pollution of air, water, and soil. In addition, sustainable landscaping promotes the coexistence of all forms of life within an ecosystem without external aid or interference. Various techniques and strategies have been developed to address environmental concerns in all stages of landscaping, from design to maintenance of both residential and commercial landscapes.

Sustainable landscaping practices are as follows:

- Achieving sustainable landscaping through the reduction of stormwater run-off with the use of bio-wastes, rain gardens, and green roofs/walls.
- Implementing water-wise garden techniques to reduce water use in landscapes, also known as xeriscaping.
- Bio-filtering wastes using constructed wetlands.
- Utilizing gray water from showers and sinks for landscape irrigation.
- Implementing Integrated Pest Management techniques for effective pest control.
- Creating and enhancing wildlife habitats in urban environments.
- Using permeable paving materials to decrease storm-water run-off and allow rainwater to infiltrate the ground.
- Incorporating sustainably harvested wood, composite wood products, and plastic lumber for decking and other landscape projects.
- Recycling materials like glass, rubber from tires, and other products to create landscape materials such as paving stones and mulch.

Model for Sustainable Buildings

Sol-Air Temperature Control

The utilization of trees, shrubs, and climbers for ventilated shading offers an effective method to regulate radiant temperature and minimize air, ground, and surface temperature. By reducing the amount of solar radiation that reaches the ground and wall surfaces, ventilated shading effectively lowers the sol-air temperature, which serves as a reliable indicator of the overall globe temperature.

Air Temperature Control

Landscaping plays a crucial role in controlling air temperature by reducing sol-air temperatures through ventilated shading. This shading, combined with evapotranspiration, involves plants absorbing water from the soil and releasing it through evaporation from their leaves. Similar to how sweating cools humans, this process removes latent heat from the air, resulting in a cooling effect.

Humidity Control

Plants can enhance the humidity of an area, which in turn can improve thermal comfort especially in hot and dry seasons. However, it is important to ensure that the plants are regularly watered. These plants absorb water from the soil, and when the water evaporates from their leaves, it raises the relative humidity and lowers the air temperature. Similarly, pools and ponds also contribute to this effect by increasing the relative humidity and decreasing the air temperature through the evaporation of water from their surfaces.

Managing Air Flow and Breeze Intensity

Plants play a crucial role in controlling wind speed and enhancing the movement of still air. Utilizing windbreaks, such as rows of trees, proves to be highly efficient in decreasing wind speed and capturing dust particles. The phenomenon known as the almond tree effect promotes air circulation beneath and around trees, even in areas where the air is relatively still.

Control Wind Direction

Landscaping techniques can be employed to manipulate the direction of wind flow. By strategically placing fences, walls, hedges, and trees, it is possible to create a barrier that redirects the wind away from or towards a building. This method is particularly effective in shielding a structure from harsh winds, such as the cold harmattan wind. Trees, in particular, are commonly utilized to guide air flow towards living areas. While trees allow some wind to pass through, they also deflect a portion of the wind above and below them. The wind that is forced to move beneath the trees enhances air circulation within living spaces. In larger areas, groups of trees can be arranged to steer the wind in a specific direction.

Control of Surface Absorption

Landscaping plays a crucial role in regulating the absorption and reflection of solar radiation on surfaces. By strategically incorporating lawns, plants, color schemes, and specific pavement materials, one can effectively manage the balance between absorbed and reflected solar radiation.

Glare Control

To prevent direct glare, one effective method is to strategically position trees to obstruct the specific areas of the sky that cause the glare. On the other hand, to prevent indirect glare, it is advisable to plant flowers, shrubs, and grass on surfaces that typically reflect light into the building. By doing so, these natural elements will help minimize the unwanted reflection and create a more comfortable environment.

Fragrance

Plants are responsible for generating oxygen and releasing fragrances, which, when combined with the almond tree effect, contribute to the creation of a rejuvenating ambiance in gardens. Although the freshness of the air and the delightful scents cannot be quantified using climatic factors, the enhancement in the microclimate is undeniably evident.

Landscape Elements for Microclimate Regulation

Microclimate regulation can be accomplished through the use of both soft and hard landscape features. Soft landscape features primarily consist of vegetation, while hard landscape features encompass a variety of elements such as structures, steps, paving, garden furniture, walls, and fences.

Soft landscaping elements

Trees and Shrubs

Soft landscaping features such as trees and shrubs play a crucial role in providing shade, controlling humidity, and influencing air movement. They are essential for achieving thermal comfort, as they have a significant impact on ventilation. Unlike hard surfaces like parking lots and sidewalks that absorb heat, trees and plants cool the air as it passes through them. Tree leaves should be strategically positioned to maximize sun exposure while offering effective shade. This natural shading is more efficient than that provided by man-made structures like roofs or walls. While a roof may provide complete shade, it absorbs heat and traps hot air underneath, leading to discomfort. In contrast, trees filter radiation, with upper leaves absorbing more heat and lower leaves remaining cooler. This allows for better heat dissipation and airflow, preventing the buildup of hot air under the tree.

Lawns and Flowerbeds

Lawns and flowerbeds serve to lower ground temperature and minimize glare. Vegetation typically enhances air quality and adds to a pleasant aroma.

Ponds and Pools

The aquatic resources serve as a means for humidification and evaporative cooling.

Hard landscaping elements

Walls and Fences

Walls serve to block the wind and can also direct its flow, whereas fences are typically constructed using various materials like stakes, rails, wire, and netting. Unlike walls, fences permit some wind to pass through, even when they have plants or climbers growing on them.

Paving materials

The selection of surface finishing, material, and construction for steps and paving can have a substantial impact on lowering ground temperature. The absence of any shade in parking lots, coupled with the use of asphalt, is a major contributor to discomfort.

Slopes and Barriers

Slopes and barriers can be highly effective in redirecting airflow on sites that have notable variations in topography.

Outdoor Living Spaces

Outdoor living spaces encompass the area that bridges the gap between the house and the garden. These spaces are designed to be both an extension of the garden and an extension of the house. They offer a degree of protection from the elements while still allowing for a connection with nature. Examples of outdoor living spaces include courtyards, patios, corridors, terraces, balconies, loggias, and porches. The design of these spaces is crucial as it can greatly influence the overall comfort of the indoor environment.

Plant Selection for Landscaping

The sustainability of a landscape largely depends on the choice of plants that are selected for it. Nonnative plants often require a significant amount of resources to thrive, whereas local plants that are well-adapted to the climate conditions will thrive with minimal intervention. Opting for native plants can also help in preventing issues with insects and pests, as these plants have natural defenses against local invaders. By selecting the appropriate local plants, expenses on pest control and watering can be reduced.

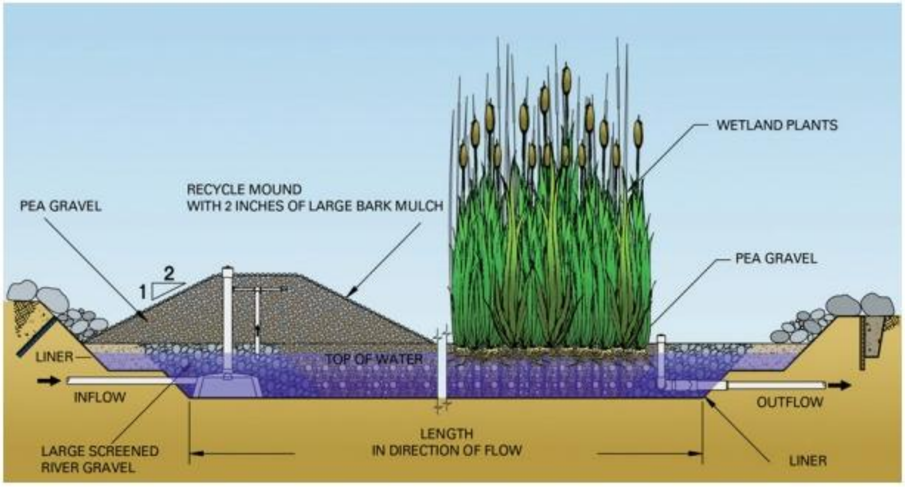

Figure 2: Sustainable Landscape approach for subsurface

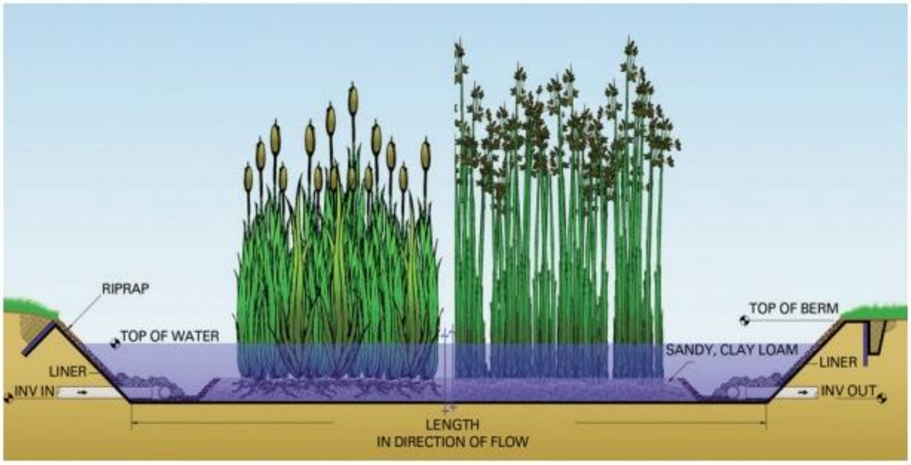

Figure 3: Sustainable Landscape approach for Surface flow

Recommendations

To promote environmental awareness and sustainable design solutions, including green building certification.

Advocate for an integrated approach to building design, involving a diverse team of professionals such as architects, engineers, and sustainability consultants.

Emphasize the use of resource-efficient building materials with low embodied energy and high life cycle value to combat the lack of maintenance culture.

Promote good Indoor Air Quality (IAQ) by selecting non-toxic products and finishes to reduce chemical contaminants in buildings.

Encourage Architects to optimize interior space design to minimize building size and resource consumption, while also considering locally produced building materials for energy and pollution savings.

Figure 4: Sustainable Landscape Approach for Parking to Drain Stormwater

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CONCLUSION

The focus of this study was to analyze the built environment and propose effective strategies for achieving sustainability through the adoption of green building practices. By embracing this approach, we can utilize our resources in an environmentally friendly and efficient manner, thereby minimizing our overall impact on the environment. Additionally, green building offers a wide range of environmental advantages compared to traditional methods, including safeguarding the health of occupants, enhancing employee productivity, conserving water and energy, and promoting an integrated systems approach in construction and other structures. Furthermore, the paper concludes with recommendations that, if implemented, would contribute to the creation of a sustainable built environment. It is important to recognize that going green not only leads to a better, healthier, and more responsible future, but it can also yield financial benefits in the long term.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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Conscious Built Environment

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Abstract— With the rise in population on earth, there is an extensive demand of built spaces or built environment in order to satisfy the requirements of human needs. Due to the rapid transformation from unbuilt to the built environment there are negative environmental impacts on air quality, ambient noise, climate etc. There are irreversible environmental changes happening like sea level rises, the melting of Arctic ice and Atmospheric Warming. There are long term impacts like global warming and climate change coming into the picture. Transformation towards the built environment is unavoidable, built environment not only includes houses or homes but it includes all other built spaces like institutional building, public spaces, Industrial areas, buildings under transportation sector etc, so rethinking built environment is very much necessary. Architecture is a branch that directly deals with designing and execution of the built environment. So, in light of the above context the purpose of the paper is to focus on a conscious built environment which shall have less negative impact on the environment.

The methodology or the approach shall be to review a few case studies and retrospect how efficiently the design can incorporate a conscious built environment for different projects. The result and findings of the paper shall focus on few guidelines derived through case studies which explain the thinking process involved in the design of some of the structures designed in India. For better understanding of the site and site context this paper shall only review Indian case studies, so as a part of Research limitation the guidelines or inferences will be restricted to Indian context only.

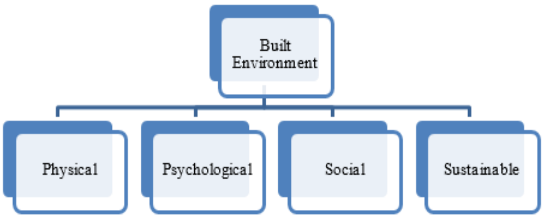
A conscious built environment is the need of the hour and we as Architects can achieve it through Climate responsive design. Climate responsive design is the basic step to achieve energy efficiency in buildings reducing negative impacts on the environment. The paper shall conclude by putting forth a few strategies which will help to achieve a conscious built environment and in a way make our mother earth a better place to live in.

Keywords: conscious, built, environment, Climate responsive design.

INTRODUCTION

Human needs are ever changing. These needs cannot be confined or kept limited. There are various reasons why there is a huge array of human requirements. If we think from global to local level, life on earth reflects extreme variations with respect to the way people live or work or conduct themselves. All the corners of the world show variety in social life, diversity in culture, differences in economic background, variation in weather conditions, differences in demand, comfort conditions and so on. Not even two different places in a single country show identical conditions. Various professional bodies, government organizations, scientists work together at local and global level to fulfil the requirements of the people. The field of Architecture is one of the professional branches which work for fulfilling the human prerequisites related to infrastructure capacities. Considering the extreme variation in the personal, local and global conditions Architecture proves to be a challenging field.

Thoughtful architectural solutions can satisfy some of the major infrastructural and comfort needs of the users. Having such a huge diversity in the climatic, geographical, cultural, behavioral, and professional conditions it is extremely necessary to produce architectural solutions in a strategic way which creates 'Built Environment' for the specific need of the users as well as the ecosystem. 'Built Environment' is nothing but a human-made set-up to achieve an atmosphere suitable for human activities.



A systematic architectural approach can positively touch upon Physical, Psychological, Social and Sustainable factors associated with human life. The factors if not looked into can show adverse effects on the lifestyle and the output.

As a user, nobody expects adverse conditions which affect the living conditions, comfort levels, unsuitable working atmosphere. There are various options possible in a building to artificially create comfortable conditions such as electrical and mechanical equipments, temporary adjustments or prohibition of certain activities. However, when a structure is under the ideation phase it is a correct time to explore the solutions to avoid future limitations. Mechanical devices can certainly provide the comfort conditions but it is at the cost of adverse effects on the environment. Firstly, it consumes loads of electricity and in addition it inherits negative effects on the human body. Human body is designed for a specific atmospheric condition. That is the reason why we find variations in the human physique from region to region. The physical design of people living in (for example) Northen part of India is peculiarly different than those living in other parts of India. This is because the human body gets adjusted with the natural environment it lives into. This is how human dwellings or housing styles have been developed so that it creates a comfortable environment within the structure depending on the region in which it is built.

Psychologically also humans need suitable conditions as it can have straight effects on the behaviour. Built environment can have noticeable effects on the mental and emotional condition of the human brain. In modern times, many cases have been observed which prove that the psychological conditions if not taken care of can have a negative impact on the results of activities performed by professionals.

Aim: The Aim of the research paper is to explore and recommend strategies required to design a conscious built environment.

Objectives: The Objective of the paper is to review case studies to understand strategies for designing a conscious built environment and to come up with a few parameters which can be considered for a conscious built environment.

LITERATURE REVIEW

With the increase in population there is a continuous rise in the demand of the built environment. The rapid growth of the built environment has also given rise to the demand of energy and resource consumption. These facts emphasize that there is an urgent need to conserve and optimize use of energy and resources. India comes in fifth position for energy requirements, of which consumption of buildings is nearly about 40% of which residences consume about 23.4% and commercial buildings consume 6.6%. Industries comes next with 30.0% and after that comes agriculture 30.7% [3]

Sustainability means self-reliance and ability to understand environmental and other impacts of developmental action (by using resources) in present times, without degrading or depriving the development opportunities of the future generation to come. So as a matter of fact resource conservation, resource management and resource generation are the basic principles of sustainable development. All the decisions pertaining to optimization of resources, efficiency of design, appropriateness of technology etc, becomes very important for sustainable architecture. Building design by way of its orientation on the site, massing of built form, orientation to sun and wind, size and scale of space orientation of activities can highly influence the living comforts and saving of energy. [4,5]

Approach towards sustainability - The process of designing is one of the most significant steps towards sustainable development. The various climatic zones like composite, warm-humid, hot-dry, cold and cloudy, cold and sunny, the wind direction, the sun path movements, rainfall data are a few of the vital statistics to be considered while designing a sustainable project. (CPWD guidelines for sustainable habitat) [1]

Energy Efficient Design and Processes - a) Passive design strategies should be adopted to build climate-responsive buildings that gives high thermal comfort inside the building consuming less energy. b) Correct orientation of the building on site with respect to sun angle and wind direction for efficient design. c) Maintain mature trees on the site and reduce the hard-paved area around the building. d) Formulation of design strategies should be according to the climatic zones mentioned in NBC. (CPWD guidelines for sustainable habitat) [1]

METHODOLOGY

Literature review is done to understand different parameters to be considered for a conscious built environment. Two case studies are also reviewed under different climatic zones of India to understand the concept of conscious built environment. First case study is from a hot and dry climatic zone and the second is from Warm and humid climatic zone. Two case studies are compared in terms of approach, technology, materials to understand how to reach up to a conscious built environment and how a conscious built environment can lead to less energy consumption and thereby contribute to sustainable architecture. Based on the literature review and case studies recommendations and conclusions are put forth in the later part of the research paper which can be followed as a part of conscious practice in Architecture.

CASE STUDY

Case Study 1: Torrent research centre, Ahmedabad by Abhikram Architects [2]

Torrent Research Centre is a pharmaceutical project with research laboratories and supporting ancillary facilities required for the project. The complex has all disciplines of pharmaceutical research with requirements of cleanest class (10000 atmosphere) to the dirtiest space emitting obnoxious gases.

In this project Architect Nimish Patel and Parul Zaveri attempted to achieve a conscious built environment by maximum light, ventilation and cooling through passive techniques to a large scale, which was accepted by the client. Both the architects convinced the client that the success of the project would be a major step forward towards energy conservation.

Geographic area: Understanding of Geographic area is one of the deciding factors of the strategies which are to be applied to the building for maximum energy efficiency. The site was in Ahmedabad which comes under the Hot and dry region of our country. As a result, the strategies which were to be taken was minimum heat gain through insulation and maximizing cool air circulation.

Use of technology: The main challenge of the project was to integrate spaces with highly controlled conditions along with the spaces which require less controlled conditions with minimum dust inside the building. In this building passive cooling is attempted through "Passive downdraft evaporative cooling system" (PDEC). This is a system where there are designated air inlet and outlet shafts. The shafts were designed in such a way that location size and heights are simulated in depth to generate the required movement of air in different spaces without using mechanical support.

The building has a climatically sealed environment. There are designated air-cooling inlets with fine spray of water and designated air outlets for the used hot air to escape. Fig- 1 on the right explains the flow of air inside and outside the building.

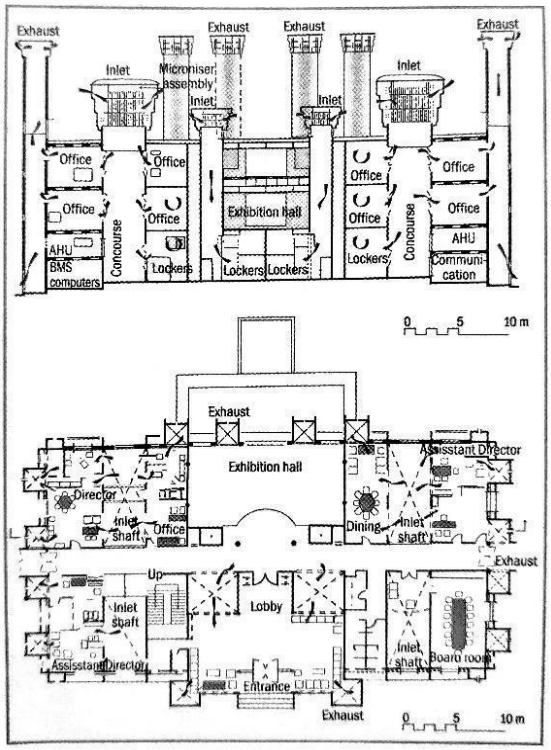


Figure 1: Plan and section of administrative block

Material: In this structure vermiculite is extensively used along with cement brickbat- based water proofing technique in the roof and cavity walls for insulation. This helped to reduce the chemical disharmony and achieve required R-value of the building materials. High glossy enamel paint is used on vermiculite plaster for the internal surface and textured cement plaster on the exterior of the building.

annually for not using artificial light during the day time.

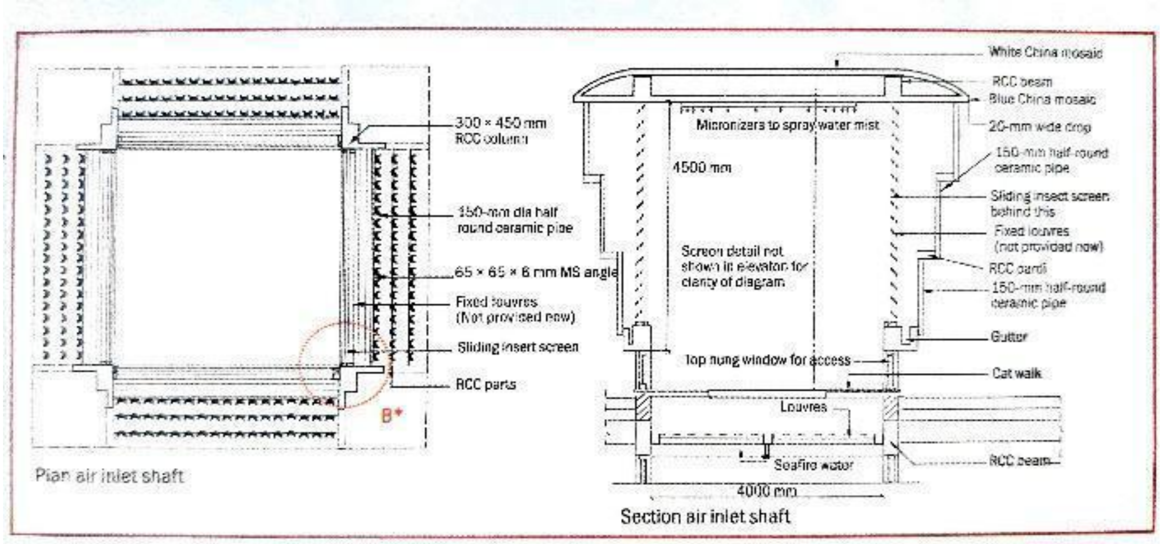


Figure 2: Details of passive downdraft cooling inlet shaft

Half – rounded ceramic pipes are used for the inlet and the exhaust shafts of the PDEC system creating local turbulence which reduces the entry of large dust particles inside the shaft. Figure - 2 below shows the plan and section of the air inlet shaft. With the help of Half – rounded ceramic pipes it was possible to replace the motor – operated shut – off louvers in the entire project saving on the energy for the same.

Observation of environment conscious approach: The building was under observation for three to four years after being occupied. It has been observed that people are comfortable inside the buildings in all three seasons i.e. summer monsoon and winter.

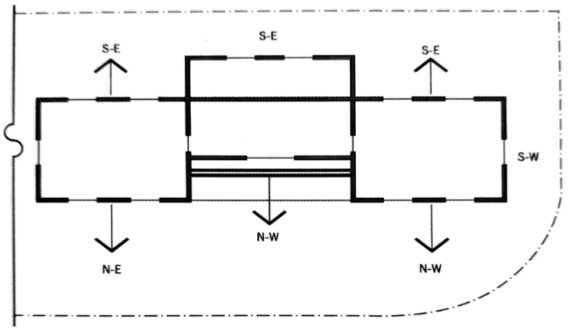
- Temperature fluctuations inside the building is not more than 4 degrees centigrade in 24-hour period in any time of the year, whereas the fluctuation outside varies as much as 14-17 degree centigrade.
- It is observed that very rarely occupants felt uncomfortable due to the fluctuation of temperature.
- Outcomes of environment conscious approach: The outcome of environment conscious approach while designing the built environment are as follows.
- There was an additional cost of 12% - 13% in the civil work for the insulation and execution of towers.
- 200 tonnes of refrigerants were saved annually, which is about 65% of the additional cost.
- Cumulative cost of installation of air-conditioning plant in a conventionally designed project of same size is Rs 5 million more.
- Saving on electricity consumption is Rs 6 million

Case Study 2: Office-cum-laboratory for the West Bengal Pollution Control Board, Kolkata by Ghosh and Bose Associates [2]

The building of the West Bengal Pollution Control Board is a government office keeping a check on the pollution control, so the Architects of the building have taken into consideration a number of strategies and technologies which aims to promote conscious and as a result sustainable built environment. The Architects and the engineers focused on the fact that the building should actively engage in uplifting of the environment and should be an exemplary case of "Environment – friendly building". The strategies for conscious built environment are explained below.

Understanding Geographic Area: Analysing / understanding Geographic area and climate is the start point towards a conscious built environment. As the site is located in a warm and humid part of the country i.e Kolkata, strategies applied in designing the building was minimum heat gain and maximum ventilation.

Site Analysis: After deciding on the major strategies based on the climate and geographic area next site analysis was taken up. The site was linear with exposure towards the South-east and North-west side. A conventional plan would have given maximum exposure towards South east and North west (Refer Fig- 3) resulting in more heat gain inside the building. So, the architects have tactfully gone for an orientation which will minimize on the heat gain



(Refer Fig- 4).

Figure 3: Site analysis of the project

Building orientation on site: After the site analysis the most important decision taken was the orientation of the building on site. The angle of the walls of the building were designed in such a way that they were maximum exposed on the East side and North side. Maximum ventilation was taken from East side with minimum openings towards the south.

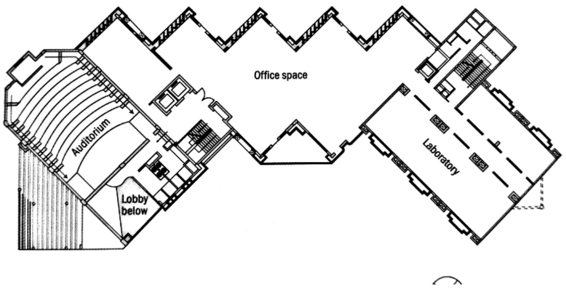


Figure 4 Activity Zoning of the project

Zoning: The entire building is strategically divided in to three parts. One laboratory wing of about 1115m2 towards the Northern exposed wall. The second one is ventilated non-air-conditioned office wing of about 1300m2, which is placed in between. The third block is the ancillary block housing entrance lobby, training center, cafeteria and mainly Auditorium on the North and North east side of the building (Refer Fig – 4). The staircase block and toilet blocks are placed toward the West façade of the building.

Planning with Sun in mind: Planning with Sun in mind helps to achieve the desired thermal comfort levels required inside the building. The staggered angular walls of the building helped to take in diffused sunlight (minimizing solar gain) with maximum ventilation which helped to reduce the electricity bill contributing to the sustainability factor.

Fenestration design: Openings were decided according to the orientation of the walls. Light shelves were designed to take in diffused light inside the building. Conscious decision was taken by the Architects that the position and size of the windows should allow maximum daylight cutting off the harsh sunlight. The decision resulted in minimizing the glare from the uncontrolled day lighting which requires curtains/blinds and thereby increase artificial lighting and cooling load.

Design for Natural ventilation: well-designed buildings in terms of Natural ventilation also plays a major role in making the building sustainable. Maximum glazing in the building was provided in North-south direction and minimum in East-west direction. Which proved to be advantageous for solar heating in winter and minimizing passive heating in

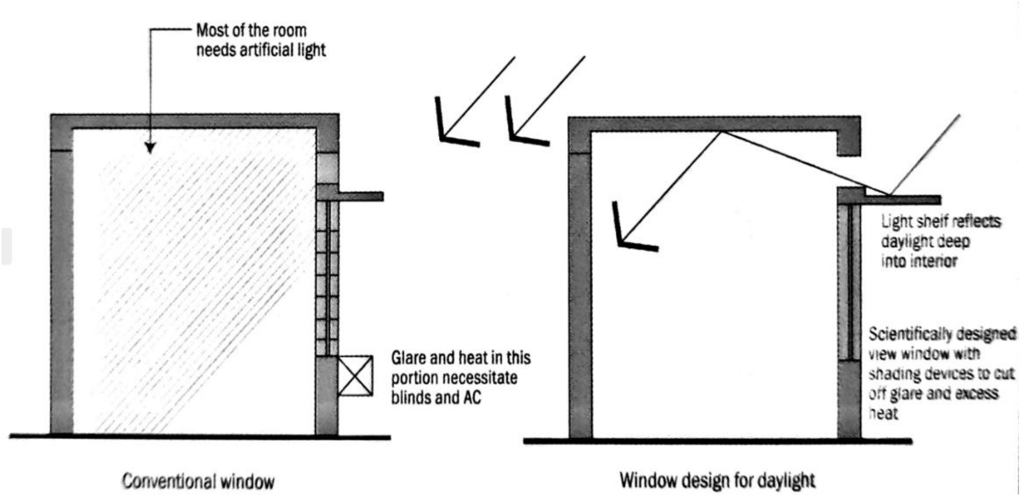


Figure 5 Traditional window and window design for integration of daylight

Table 3 Consumption and saving on one typical floor

Area	Case	Lighting consumption (kWh)	HVAC consumption (kWh)	Total consumption (kWh)	Savings (%)
North-facing laboratory	Conventional window/ shading	5070	11592	16662	–
	Final design	936	10080	11016	33.9
South-facing laboratory	Conventional window/ shading	2150	5760	7910	–
	Final design	624	5328	5952	24.7
Office block	Conventional window/ shading	12960	–	12960	–
	Final design	624	–	5160	24.7
One typical floor	Conventional window/ shading	20180	17424	37608	–
	Final design	7170	15408	22578	39.8

Source TERI. 1996. **Design review of West Bengal Pollution Control Board Building at Salt Lake, Kolkata** New Delhi: Tata Energy Research Institute [TERI report 1995RT65].

summer. This particular orientation is best suitable for ventilation according to the prevailing wind in Kolkata city. The decision helped to reduce the cooling load on air-conditioning.

Scientific design of shading devices: Shading devices are calculated and designed according to the orientation and direction of the walls. Two principals taken up while designing the shading device are reduction of thermal load of the building and control of glare inside the building. Combinations of horizontal and vertical louvers are done to cut off summer sun, allowing the winter sun inside the building. Software simulations were done to compare the energy consumption and finally the shading device was decided

Conduction of Modelling and Analysis: Energy simulation software was used to decide on the light levels and thermal performance of the building with different sizes of the windows. window sizes. After model analysis the size of the fenestration is finally decided for the building.

Outcomes of environment conscious approach: The above-mentioned adaptations and conscious approach towards design resulted in various positive impacts in cutting down the load on energy consumption.

The table on the right (Table 1) shows the percentage of energy saving on all the activity areas of the building such as North-facing laboratory (33.9%), South-facing laboratory (24.7%), Office block (24.7%), one typical floor (39.8%).

So totally 39.8% of energy is saved by controlling size and shape of window design and shading device design, also 2.6% energy is saved through solar passive techniques, altering the orientation, depth of

plan etc. Hence by adopting Passive design strategies a total AA conventionally designed building of the same type.

INFERENCE

A comparative study is done between an Artificial built environment and a consciously built environment to understand the pros and cons towards the environment.

Table 2 Showing comparative study between artificial and conscious built environment

Strategies	Artificial built environment	Conscious built environment
Approach	not consciousness towards environment	consciousness towards environment
Impact towards environment	negative impact	positive impact
Light and ventilation	forced	natural
Energy consumption	heavy	less
Energy Saving	no saving	comparatively better saving
Maintenance	heavy	less
Costing	huge investment	initially more but better payback
user comfort	temporary	permanent
user efficiency	achievable	achievable
planning designing scope	not much of thought required	thoughtful process required to integrate passive architecture
Sustainability	not based on the principles of sustainability	based on the principles of sustainability
Net zero approach	doesn't follow Net zero approach	towards Net zero approach
Passive Design strategies	doesn't follow passive design strategies	follows passive design strategies
Climate responsive architecture/design	not required to follows climate responsive architecture/design	follows climate responsive architecture/design

DISCUSSION AND FINDINGS

The inferences above allow us to study both the methods of achieving comfort conditions. The comparison between the artificial environment and conscious built environment clarifies the advantages of the later considering the environment-conscious efforts of designers. Artificial installations can certainly create temporary comfort conditions but it can not be adopted as a permanent solution for the reason that a consciously built environment proves to be superior on the parameters of sustainability, energy consumption, user health, and a climate-responsive approach. The case study discussion can help understand the scenario in a better way.

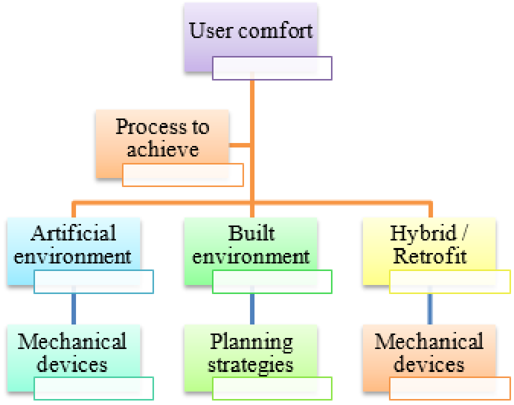
In Case study 1: First and foremost, conscious step towards the project was taken by the principal architects of the project (Architect Nimish Patel and Parul Zaveri). They managed to convince the client that human comfort will be achieved through extensive use of natural light ventilation and thereby setting forward an e.g of a conscious built environment. As a part of the passive design PDCE system was proposed and executed in the project. The PDEC system helped to minimize use of conventional air conditioning systems and in turn saved on electricity. Also the natural lighting system helped to save on the electricity for not using artificial light during the day time.

In Case study 2: The conscious decision was taken by the Architects and the engineers to focus on the fact that the building should actively engage in uplifting of the environment and should be an exemplary case of "Environment – friendly building". By using passive design strategies, the cooling load for air-conditioning was reduced to a great extent in the building. Efficient planning, fenestration design, orientation, and scientific design of shading devices has helped to reduce the energy consumption by 40% over a conventional building of the same size.

Recommendations

Architectural strategies play a vital role in human behavioral control. Human brain is a tool which performs superior in comfort conditions. A stressful atmosphere or uncomfortable conditions around severely affect the human output and ultimately dent the desired result. The studies have proved a strong relation between thermal, visual, physical comfort conditions and human brain outputs. [9] There is a need for an interdisciplinary approach between behavioral science and the architectural and interior design process. 'Built environment' precisely creates a strong link between the two. It is responsible for 'establishing' the desired physical, visual and thermal conditions which are responsible for better output and maintaining effective brain function for the users.

There are few processes which can be discussed in order to achieve the comfort conditions for the users. There could be various strategies which can be thought of as a part of the solution to the designs. The design could be approached in a way that the entire comfort condition parameter is dependent on the artificial mechanical system where there is very minor consideration for environmental strategies. [8] In such a strategy, there is a dependency on mechanical equipment to achieve the comfort conditions. There is no doubt that such a system



'creates' a quick comfort condition for the users and is also hugely practiced in the industry. However, it carries certain negative effects on the environment as a result. It becomes unavoidable to be dependent on the energy consumption to keep the devices working throughout the working span. Considering the working hours in commercial spaces of metro cities this working span calculates the entire day and full week. The study also suggests that the outdoor units of the air-conditioning systems increase the atmospheric heat. Sudden change in temperature can have adverse effects on the human body as well. In existing buildings, the comfort conditions can be achieved by addition of mechanical devices. This could be the best possible solution for existing buildings because making structural changes has limitations.

The entire discussion therefore leads to logical architectural solutions for the structures at the time of designing. If the designs are crafted to take a maximum advantage of the existing environmental conditions of the region it is being designed for, it assures the best desired results with minimized energy consumption. 'Conscious Built environment' strategies are nothing but the consideration environmental conditions available and taking maximum advantage of the same to achieve best possible comfort conditions for the users by minimizing the negative impact on the environment. The case studies discussed in this research reflect that if the structures are designed with the conscious built environment strategies can not only bring down the operation cost but also helps in attaining best possible comfort conditions eventually upgrading the user satisfaction and performance.

The study therefore recommends that as a conscious professional it's a duty of the architects to discourage or minimize the unnecessary use and dependency on the mechanical devices for achieving the comfort conditions and encourage the clients, users to shift towards the conscious built environment. This could be managed through 'environmental literacy' for the designers as well as the developers and end users. The world is currently struggling to mitigate larger issues like global warming and initiatives like 'Conscious built environment' can definitely prove in line with our fight against such problems. It is an architects' duty to take a first step towards the environment friendly buildings by considering the passive design strategies to create comfort conditions for the users.

CONCLUSION

Consciousness is something related to self-reliance, how our design can cause the least negative impact on the environment. Every decision pertaining to optimization of energy, appropriate use of technology and efficiency of design contributes to sustainable architecture. Conscious approach plays a vital role in the designing and execution of a built environment. Sometimes it is not possible for the owner/client of the project to foresee the negative impact on the environment due to execution of the project but as an architect or engineer it is our duty to make the client aware about the sustainability factor and convince the client to take a step forward towards the direction of energy conservation. Understanding of Geographic area, climate condition, material, passive strategies and designing accordingly will lead to a conscious built environment. It is possible that the initial cost of execution of the project can be more for execution of passive strategies but it will pay back at due course of time. [6,7]

As discussed in the study, in current scenario most of the projects aim to achieve comfort conditions for the users by providing artificial resources which is considered to be the simplest possible way. The introduction of artificial sources has short-term success. It is a myth that designing with environmental strategies brings limitations in the design outputs. However, the case studies discussed suggest that in structures designed with 'conscious built environment' strategies multiple issues can be addressed at the same time. A thoughtful and sensible approach to design can bring down energy consumption, enhance productivity, reduce the adverse impact on the ecosystem, protect natural resources, and reduce maintenance expenses which are considered to be long-term achievements.

An effort at a local level can certainly contribute towards global sustainability. Collectively these efforts can bring the much-required change at the broader level. To secure a better and environmentally safe future we need to prepare ourselves at the right stage.

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Exploring Green Design Features Contributing Towards Form and Iconicity of Tall Buildings

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Abstract— Several iconic tall buildings with significant green design features (GDFs) have emerged on urban skylines across the globe in the recent past. The iconicity of a building refers to its fame and visual significance. Nevertheless, iconic skyscrapers are often criticized as obsessively concerned about self-expression, disregarding their location's historical, cultural, climatological and architectural context. This article explores the contribution of the GDFs towards the form and iconicity of selected new-generation skyscrapers, adopting a qualitative study approach. Three frequently deployed green design features, namely vertical landscape, shading device, and exoskeleton have been explored with eleven well-known tall iconic buildings. The study outcome upholds that the human quest for achieving a consonance between sustainability and iconicity is a powerful force driving the evolution of many emerging skyscrapers. The harmonious integration of the GDFs is vital for achieving sustainability and leads to extraordinary architectural achievements in creating environmentally responsive and visually captivating skyscrapers. Scopes of further research are identified.

Keywords: Climate resilient; Green design features; Iconicity; Skyscrapers; Tall building; Vertical landscape; Shading device; Exoskeleton; Sustainability.

INTRODUCTION

In a remarkable leap towards sustainability, a new generation of skyscrapers has emerged on the urban skyline for the last few decades. These architectural marvels incorporate a range of innovative and eco-friendly GDFs, exemplifying a blend of form, function, and environmental consciousness. The GDFs frequently include vertical landscaping, brise soleil and exoskeletons, among others. With a focus on GDFs, we witness the evolution of skyscrapers transcending beyond structural wonders with steel, concrete and glass, and several such buildings are globally recognised as iconic structures.

The iconicity of a building refers to its fame, resulting from symbolic and, or aesthetic significance. Iconic buildings are landmarks often symbolising community identities. These buildings provide the communities with backdrops to connect and relate to themselves, thus cultivating a sense of ownership and pride (Sklair 2010). Nevertheless, skyscrapers are often criticised as urban icons meant for publicity and the exhibitors of luxuriance and exclusivism. Repeatedly, the giant icons are highly individualistic and obsessively concerned about self-expression, disregarding the historical, cultural, climatological and architectural context (Moldovan, Ioana; Moldovan, Silivan Valentin; Nicoleta-Maria 2014)).

Concerning the above dichotomy, this article delves into selected remarkable skyscraper projects that exemplify the fusion of sustainability and iconic design. Through this exploration, we uncover design approaches that successfully achieve both sustainability and iconicity while underscoring the profound effects of intentional sustainable design.

The next section delves into the existing literature, followed by the methodology adopted for this research. How green design architectural features contributed to the iconicity of the buildings is discussed in Section 4. The article concludes with a discussion of the future research scope.

LITERATURE REVIEW

Tall buildings cause more environmental problems in their life cycles than low-rise buildings. Concerning these problems, architects have been increasingly paying particular attention to the carrier systems and sustainability issues while designing tall buildings. Several scholars have reviewed the GDFs of tall buildings, especially those certified by Leadership in Energy and Environmental Design (LEED). The reported GDFs include wind turbines, building-integrated photovoltaic (BIPV) systems, on-site cogeneration plants, natural gas-fired cogeneration systems, Central Energy Plants, rainwater harvesting systems, greywater and blackwater recycling systems, low-flow fixtures, waterless urinals, geothermal systems, low-E coating, shading systems and heat-reflecting ceramic frit, automated and operable windows, solar chimneys, gardens with water features, under-floor air distribution (UFAD) systems, CO2, CO, VOCs and SPM monitoring stations, sensor-based air filtration systems, vertical landscaping and green roofs, aerodynamic form, exoskeleton and others (Al-Kodmany 2018, 2022, 2023; Rafiei and Adeli 2016; Utomo et al. 2022). While these studies focus on the functionality of the GDFs towards sustainability, their contribution to architectural iconicity remains less explored.

Iconicity plays a pivotal role in the world of architecture, granting a building its prestigious status and accomplishing the ultimate design objective. The significance of iconic tall buildings spans numerous fields, captivating the attention and admiration of the beholders. Iconic tall buildings possess unique characteristics that distinguish them from their counterparts. Numerous studies have delved into the realm of skyscrapers, aiming to gauge the degree of iconicity while unravelling the reasons behind the failures of certain lofty structures in attaining this coveted status (Gaber, Maarouf, and Fath2022 ; Karimimoshaver and Winkemann 2018; El Messeidy 2019; Sev and Özgen 2009; Tanju Gültekin 2017; Al Tawayha, Braganca, and Mateus 2019; Wang, Zhao, and Jia 2021). Gang (2008), a prominent architectural critic, highlights that many contemporary tall building designs lack genuine architecture (Gang 2008). They resort to employing eccentric forms in a desperate bid to vie for attention, ultimately failing to respond harmoniously to their context and climate.

Nevertheless, the tides are turning, as a few recent articles have focused on eco-iconic skyscrapers (Al-Kodmany 2014; Kodmany 2010). These articles emphasise the possibility of achieving both iconicity and sustainability simultaneously, further calling for in-depth investigations regarding how various GDFs can contribute to the iconicity of tall buildings. Hence, this article sets out to study the correlation between green design and the attainment of iconic status in towering structures.

METHODOLOGY AND DATA

The current study adopts a qualitative and exploratory approach using secondary data gathered from the literature. Three frequently deployed green design features, namely vertical landscape, shading device and exoskeleton, have been explored with eleven iconic tall buildings selected worldwide following the principle of purposive sampling(Grossoehme 2014).

ANALYSIS

Vertical Landscape (Garden)

Vertical gardens (VGs) refer to self-sufficient landscaping imparting features to the facades of a building, resting on its outer or inner walls. Special irrigation systems installed on the building provide the plants with water and nutrients. VGs on building facades are welcome on several counts. It shades the interior from direct sunlight, stops harmful ultraviolet radiation from passing through, and facilitates making the indoor air cool, fresh and clean. Thus, it reduces the air conditioning load and operational energy costs. It also reduces the heat flow into rooms by lowering the temperature of the building's exterior walls. VGs create better living conditions in the adjacent space by enriching the air with oxygen. VGs absorb sound and thus can reduce background noise significantly (Golasz-Szolomicka and Szolomicki 2019; Ischenko and Shishkunova 2021). With careful species selection, the building facades keep transforming as the flowers bloom and foliage change their colours with the seasons. Blooming flowers attract bees and birds, thus uniting the facades with nature.

Conceptually, VGs are of two categories: First, "Vertical Forest", which involves the installation of portable soil containers with plants on purpose-built consoles, platforms, terraces and building facades; second, "Living Wall", in which modular racks are installed for placing vegetation directly. Living Wall systems are of two types: felt system (hydroponics) and panel system (with substrates) (Bahrami 2014).

Beyond their contribution towards environmental sustainability, VGs dramatically add to the dynamic aesthetic appeal of building facades and, thus, render the building iconic. Two frequently referred instances of vertical gardens are One Central Park, Sydney, Australia and Bosco Vertical Towers, Milan, Italy (Figure 1).

(a) One Central Park, Sydney, Australia
Source: https://parametric-architecture.com/are-vertical-gardens-in-skyscrapers-the-future-of-sustainable-urban-living/

(b) **Menara Mesiniaga, Selangor, Malaysia**
Source: https://parametric-architecture.com/are-vertical-gardens-in-skyscrapers-the-future-of-sustainable-urban-living/

Figure. 1: Examples of Vertical Landscaping and Green Façade in High -Rise buildings

One Central Park, Sydney, Australia, designed by the French Ateliers Jean Nouvel and Urbis Pvt. Ltd., is a mixed-use, highrise (117 meters) building near the Central Station. It was officially opened in December 2013 and won 'The Best Tall Building in the World' in 2014, awarded by the Council for Tall Buildings and Urban Habitat (CTBUH). This skyscraper has a sky garden roof and VGs that may accommodate 35,000 plants. The project comprises an East Tower (33 floors) and a West Tower (16 floors), linked by a five-storey podium. The VGs belong to the "Living wall" category, adopting the hydroponic system that supports plant growth without soil. Building management system-regulated mechanical arrangements supply the light, carbon dioxide, water, and nutrients to foster the plants without affecting the building's structural integrity. The plant species are selected and placed to maximise heating and natural lighting from direct sunlight and provide organic shading. Consequently, the operational energy consumption for the active systems is reduced, rendering the project energy-efficient. Also, the building reflects less heat, unlike conventional shading devices.

The Bosco Verticale Towers in Milan, designed by the Italian architect Stefan Boeri, won the 'The Most Beautiful and Innovative High Rise Buildings in the World' in 2014. The project comprises two residential towers, one of 112 meters in height and the other of 80 meters. Housing about 800 tree species, 11,000 perennials and covering plants, and 5,000 shrub species, the project epitomises a new model of iconic architecture contributing towards microclimate mitigation with ever-vibrant facades.

Shading Device

Glare from glass surfaces constitutes a significant concern in modern buildings' external and interior designs. The stark contrast between brightly illuminated areas exposed to direct sunlight and adjacent darker zones contributes to the manifestation of glare. Studies indicate that a single south-facing window can amplify illumination levels from 20 to 100 times its unit area, leading to the frequent glare in regions surrounding sunlit windows within buildings. This phenomenon is particularly pronounced when substantial light converges onto a confined space. The factors influencing solar management about heat gain are intricately linked to the local climate and the orientation of building facades. The global architectural landscape has witnessed a discernible trend favouring highrise constructions characterised by Western-style all-glass curtain walls. However, this approach often overlooks regional climate patterns, necessitating the integration of effective sun shading devices to address associated challenges.

Solar shading devices have emerged as indispensable tools for managing glare and heat gain in response to the increasing prevalence of all-glass structures. Notably, the context of highrise constructions in hot climates, exemplified by regions like Abu Dhabi, where intense sunlight routinely elevates temperatures above 38 °C (100 °F), underscores the ecological and economic challenges associated with cooling all-glass buildings. Therefore, Sun shading devices play a pivotal role in enhancing such structures' energy efficiency and sustainability. Beyond their functional roles in glare reduction and heat management, sun shading devices contribute to the aesthetic appeal of architectural designs. Their integration can be both practical and visually intriguing, allowing architects and designers to harmonise functional requirements with creative expressions.

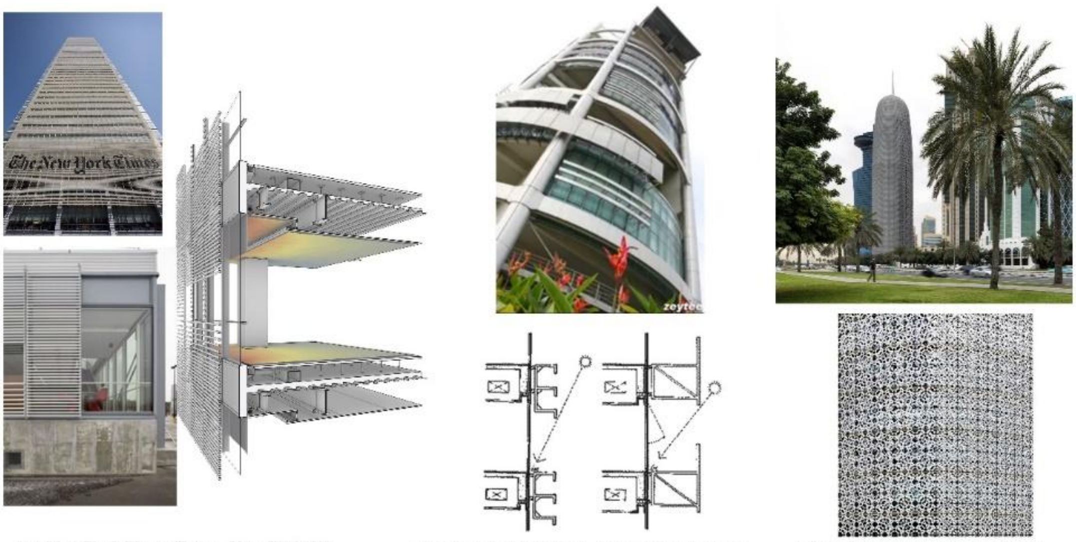
Static solar shading device

Static solar shading encompasses various elements, including sunshades, light shelves, blinds, fins, overhangs, horizontal louvres, vertical louvres, and shade cloth. These elements serve practical purposes and contribute to a structure's visual identity (Al-Tamimi and Fadzil 2011; Jayaweera, Rajapaksha, and Manthilake 2021; Mangkuto et al. 2022). For instance, fins can emphasise a building's verticality, while cantilevers draw attention to its horizontality. Noteworthy examples from contemporary architecture, such as the New York Times Tower, Menara Mesiniaga, and Doha Tower, showcase how architects can creatively integrate static shading devices to achieve functional and visual objectives (Figure 2).

The New York Times Tower stands out as an exemplar of creative solar shading design (Figure 2a). The American Institute of Architects' 2007 survey list of America's Favorite Architecture ranked the New York Times Building among the top 150 buildings in the United States. In addition, the building received the American Institute of Architects' 2009 Honor Award. It has won many other awards, including the 2010 CTBUH "Best Tall Building Americas Winner" award. Its brise soleil, composed of 186,000 ceramic rods connected to a controllable lighting system, is a functional shading device and a distinctive architectural feature. Architect Renzo Piano's conceptualisation of the screens as a "suncoat" rather than a "raincoat" highlights their role in excluding heat and light while allowing the use of transparent glass.

Similarly, Menara Mesiniaga, situated in Subang Jaya, close to Kuala Lumpur, incorporates repetitive curved aluminium sunscreens, imparting a unique visual style to the structure (Figure 2b). The interplay of form and function in this design showcases the potential of static shading devices to enhance a building's aesthetic appeal. This tower received the prestigious Aga Khan Award for Architecture in 2007.

In Doha Tower, Qatar, the architect Jean Nouvel reimagines the traditional mashrabiyya by dynamically adjusting its density according to the sun's direction (Figure 2c). This innovative approach provides a contemporary interpretation of a conventional element, showcasing the adaptability of static shading devices in responding to environmental conditions. CTBUH recognised Doha Tower as the 2012 Best Tall Building in the Middle East and Africa, and also the Best Tall Building Worldwide.



(a) New York Times Tower, New York City
Sources: https://alexanderayres.com/New-York-Times-Building
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(b) Menara Mesiniaga, Selangor, Malaysia
Sources: https://sigit2006grondgebied.wordpress.com/4-actual-works-and-ideas-for-the-future/43-menara-mesiniaga-kuala-lumpur-malaysia-by-ken-yeang/

(c) Doha Tower, Doha, Qatar
Sources: https://the.akdn/en/en/how-we-work/our-agencies/aga-khan-trust-culture/akaa/doha-tower

Figure. 2: Application of static solar shading devices in tall

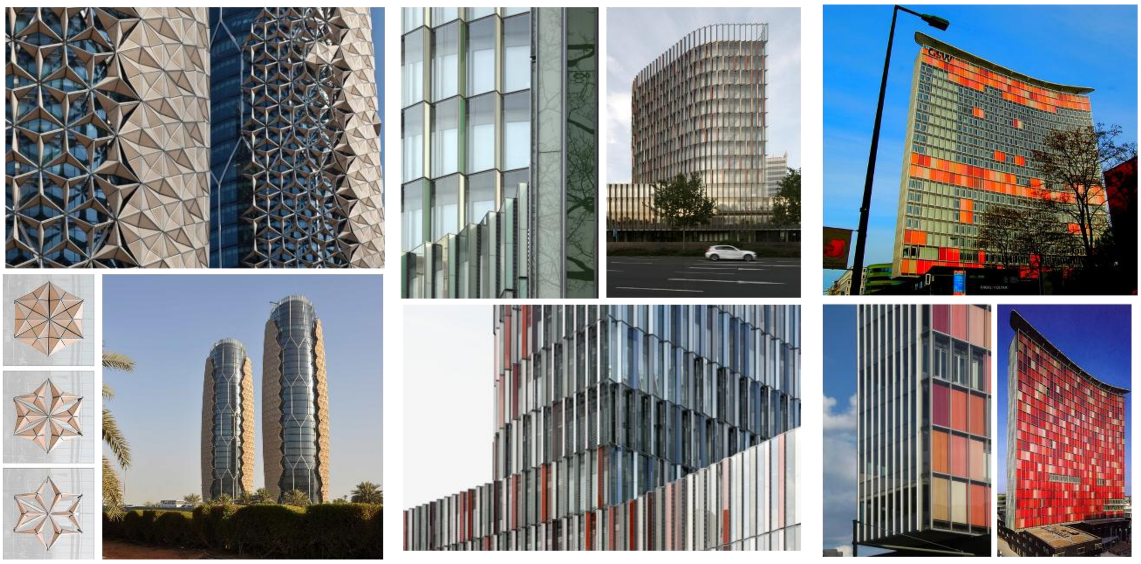
Dynamic solar shading devices

Dynamic solar shading devices represent a paradigm shift in architectural design, offering a responsive solution to the challenges posed by sun exposure (Al-Masrani and Al-Obaidi 2019). This section explores three distinctive examples that highlight the dynamic nature of these shading systems—Al Bahar Towers, KfW Headquarters, and GSW Headquarters, Berlin-Kreuzberg (Figure 3). Through dynamic responses to environmental conditions, these structures optimise energy efficiency and elevate the visual aesthetics of their facades.

The Al Bahar Towers, Abu Dhabi, UAE, is a pioneering example of modernising the traditional mashrabiyya (Figure 3a). This tower was named a 2013 CTBUH Innovation Award Winner and a 2013 Best Tall Building Middle East & Africa Finalist. In contrast to traditional designs' static and two-dimensional nature, Al-Bahar's mashrabiyya is dynamic and three-dimensional. This innovative system opens and closes in response to the sun's position, following a hexagonal pattern inspired by traditional Arabic-Islamic design. Parametric and computational modelling optimise the placement of the mashrabiyya on the facade, eliminating the need for dark-tinted glass. The towers' ever-changing appearance stimulates captivating aesthetics while reducing solar gain by 50%, resulting in significant energy savings and reduced CO_2 emissions (Elghazi and Mahmoud 2016).

The prestigious accolade for the World's Best Tall Building was awarded to the KfW project by CTBUH in 2011. The KfW Headquarters in Frankfurt, Germany, showcases a dynamic visual expression using polychrome ventilation flaps on its façade (Winterstetter and Sobek 2013) (Figure3b). These narrow flaps, adorned with varying shades of red, blue, and green, enhance the building's visual appeal and serve a functional purpose. Environmental sensors integrated with the Building Management System (BMS) dynamically control the ventilation panels, ensuring a uniform pressure inside the building ring. The dynamic colour composition, influenced by the shifting positions of the ventilation panels, creates a vibrant play of colour across the facade. This dynamic approach contributes to visual aesthetics and optimises the building's internal environment.

The GSW Headquarters in Berlin-Kreuzberg has garnered widespread acclaim and numerous prestigious awards, including nominations for the Stirling Prize and the European Union Prize for Contemporary Architecture (Figure 3c). Its remarkable design and adaptive features stand out, particularly emphasising the façade as a multifunctional component (Figure 3c). The east façade boasts triple-glazed windows equipped with blinds nestled between the panes. The west façade adopts a dual-skinned approach with double-pane windows on the inner side. Manual and automatic operation options are available for the windows on either façade, providing occupants with control over sunlight penetration and privacy. The interstitial space in the west façade is adorned with wide, vertical, perforated aluminium louvres in vibrant colours, creating an external solar shading system. On sunny days, these coloured elements harmonise, forming a captivating carpet that shades the entire west façade. The double glass on the west façade facilitates natural air conditioning through a chimney effect induced by cross ventilation. This innovative approach results in a remarkable 40% reduction in energy usage compared to German energy standards. The system controls airflow by manipulating dampers at the top and bottom, enhancing natural ventilation within the building. Moreover, the system regulates artificial lighting based on available daylight, ensuring optimal energy utilisation. Real-time controls enable the automatic adjustment of coloured louvres on the west façade, contributing to the building's dynamic aesthetic. An essential feature of the system is its user-specific control, allowing occupants to override the automated settings. Zonal controls are strategically placed at all window sill levels, allowing users to tailor their environment. During overrides, the Building Management System communicates recommendations through red and green lights, enhancing user awareness and promoting energy-conscious decisions.



(a) Al Bahar Towers, Abu Dhabi, UAE

Sources: Elghazi YS, Mahmoud AHA. Origami Explorations A Generative Parametric Technique For kinetic cellular façade to optimize Daylight Performance. In: Proceedings of the International Conference on Education and Research in Computer Aided Architectural Design in Europe. 2016. p. 399–408. https://www.iaacblog.com/programs/parametric-skins-al-bahar-towers-2/ https://www.archdaily.com/270592/al-bahar-towers-responsive-facade-aedas

(b) KfW Headquarters, Frankfurt, Germany

Sources: https://www.archdaily.com/316143/kfw-westarkade-sauerbruch-hutton

(c) GSW Headquarters, Berlin-Kreuzberg

Sources:https://en.wikiarquitectura.com/building/gsw-headquarters/

Figure. 3: Application of dynamic shading device in tall building

Exoskeleton

Exoskeletons are external protective hard coatings found in some animals, primarily arthropods. These support the creatures' body as well. In architecture, exoskeletons refer to a construction approach that puts the key components of a building on the exterior of the structure, thus exhibiting its technical aspects. Exoskeletons in tall structures serve a dual purpose by providing structural stability and enabling free-column interior areas (G. and M. 2019). Comparable to braced and diagrid systems, exoskeletons introduce distinct structural manifestations that redefine the aesthetics and functionality of skyscrapers. In recent years, the integration of exoskeletons in skyscraper design has emerged as a revolutionary solution, offering unique advantages in terms of structural stability, interior space optimisation, and sustainable features. This section explores the evolution of exoskeletons in skyscraper design, focusing on notable examples, namely, the O-14 Tower in Dubai, the Menara Mesiniaga and the Oasia Downtown in Singapore (Figure 4).

Completed in 2010, the 24-story O-14 Tower in Dubai is a testament to the innovative use of exoskeletons (Figure 4a). The O-14 was named "Best Tall Building Middle East & Africa Finalist" by the CTBUH in 2012. The tower features a concrete façade with circular apertures, creating a lace-like exterior that breaks the monotony of traditional skyscraper facades. Positioned one meter from the glass enclosure, the exoskeleton produces a chimney effect, allowing heated air to ascend and establishing an effective passive cooling system. Beyond its architectural significance, the O-14 Tower's exoskeleton serves as its primary structural element, relieving the core of lateral force loads and creating a column-free interior space of approximately 557 m2 (6000 ft2). The diagrid design of the exoskeleton strikes a delicate balance between material strength and aperture size, contributing to the tower's overall structural effectiveness.

The Menara Mesiniaga's exoskeleton is a defining feature, both a structural support system and a design element (Figure 4b). Each uniquely shaped office floor is suspended with main girders connected to a central concrete core for shear resistance. What sets this building apart is the decision to expose the structure, taking advantage of the tropical climate to mitigate temperature-related effects. In response to the tropical climate, the curtain wall shields the exposed structure, serving a dual purpose. It acts as a barrier against direct sunlight, preventing unwanted heat gain and functioning as a heat sink. This innovative design significantly contributes to achieving thermal comfort within the building. Strategic use of the curtain wall optimises the need for mechanical cooling systems, reducing energy consumption (Ip and Jahnkassim 2000). The Menara Mesiniaga employs a thoughtful approach to solar shading, utilising the overhang of the curvilinear roof to shade the entire south façade from the high-angled afternoon sun. This strategic use of architectural design minimises solar heat gain, reducing the overall cooling load on the building. Incorporating these shading strategies enhances occupant comfort and demonstrates a commitment to sustainable building practices. The crowning feature of the building, a tubular steel trellis, provides shade to the top-floor amenities and is designed to accommodate future solar panels. This forward-thinking approach aims to enhance the building's ecological efficiency by harnessing renewable energy sources. The Menara Mesiniaga exemplifies a noteworthy holistic design principle that prioritises environmental sustainability without compromising architectural integrity.

Oasia Downtown in Singapore redefines the role of exoskeletons by integrating greenery into its façade (Figure 4c). Using an aluminium mesh covered with 20 species of blooming vines and creepers, the building achieves a remarkable 750% replacement 'green value.' The plants cool and cleanse the air, provide shade and absorb heat. The tower's aesthetic changes with the seasons as the plants grow and change colour, creating a dynamic and visually appealing exterior. Importantly, the low-maintenance nature of the selected plants eliminates the need for constant attention, reflecting a commitment to sustainability in skyscraper design. The structure was named "CTBUH Best Tall Building Worldwide" in May 2018.

(a) O-14 Tower in Dubai
https://www.archdaily.com/273404/o-14-reiser-umemoto/505241fb28ba0d16c3000249-o-14-reiser-umemoto-photo

(b) Menara Mesiniaga, Selangor, Malaysia
Sources:https://www.researchgate.net/publication/343810006_Toward_More_Sustainable_Buildings/figures?lo=1

(c) Oasia Downtown, Singapore
Source:https://www.skyscrapercenter.com/building/oasia-hotel-downtown/14114

Figure. 4: Application of exoskeleton in tall buildings

CONCLUDING REMARKS

This article delves into the transformative power of sustainable skyscrapers by exploring the intersection of GDFs and iconicity. The quest for achieving a consonance between sustainability and iconicity is a powerful force driving the evolution of skyscrapers. The exemplary skyscraper projects explored in the current article demonstrate that sustainable design is a necessity and catalyst for extraordinary architectural achievements. By embracing the GDFs, these skyscrapers shape the skyline of a greener and brighter future. As we explore these GDFs and their contribution to the form and iconicity of tall buildings, it becomes evident that sustainability and aesthetic appeal are not mutually exclusive. The harmonious integration of these elements showcases the limitless possibilities of sustainable design, inspiring future generations of architects and urban planners to create environmentally conscious yet visually captivating skyscrapers.

The present study prompts further research that would undertake a detailed and quantitative assessment of the benefits derived from the GDFs during the service life of the buildings under the reference. A comparative assessment of the increased cost for the GDFs, if there is at all, and their benefits would provide an ins-depth understanding of the synergy between sustainable design and iconicity.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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