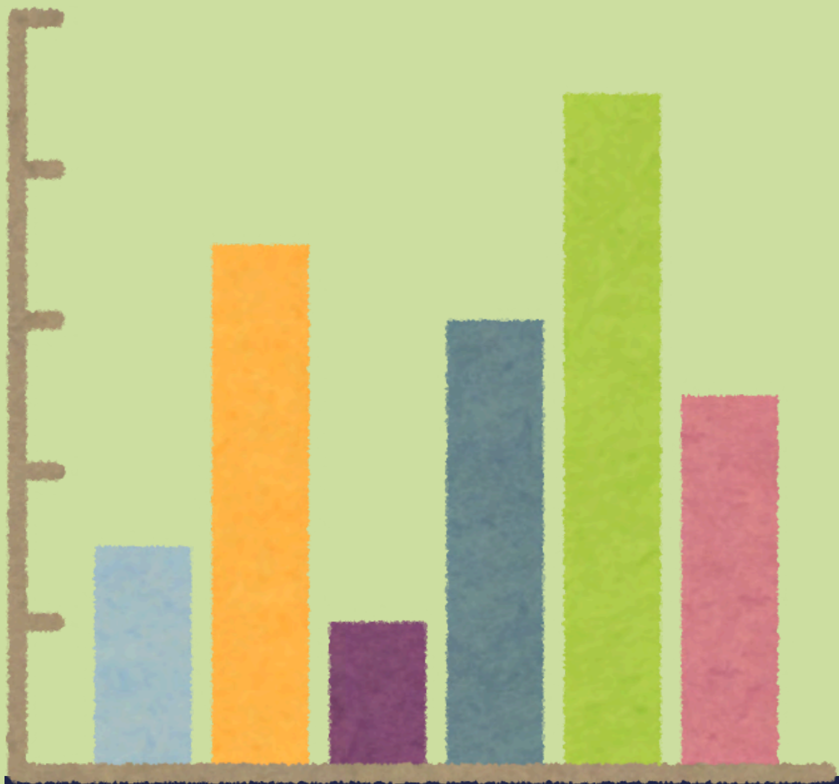
ISBN- 978-93-342-4408-3

ONLINE NATIONAL CONFERENCE ON :

ADVANCED ARCHITECTURAL AND PLANNING PRACTICES

BRIDGING INNOVATION, SUSTAINABILITY AND DESIGN

(ELECTRONIC VERSION)



A Collection of Research Papers

10th and 11th July, 2025

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https://mbscollege.org

MBS College, Sector-9, Dwarka, New Delhi - 110077
(Affiliated to Guru Gobind Singh Indraprastha University,Delhi and approved by CoA & AICTE)

MBS COLLEGE

PROCEEDINGS BOOK

NATIONAL CONFERENCE
ON

"Advanced Architectural And Planning Practices"

Bridging Innovation, Sustainability and Design

10th & 11th July, 2025

ORGANIZED BY

MBS COLLEGE

DWARKA SECTOR 9, NEW DELHI

(Affiliated to Guru Gobind Singh Indraprastha University, Delhi
and approved by CoA & AICTE)

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ISBN : 978-93-342-4408-3

Published by MBS College
PSP Area, Sector-9, Dwarka, New Delhi-110077
011-25071504, 28082960
www.mbsarchitecture.org

About MBS College

MBS College, established in 2009 as the MBS School of Planning and Architecture, is a prominent institution affiliated with Guru Gobind Singh Indraprastha University (GGSIPU). Initially recognized for its Bachelor of Architecture (B.Arch) program, the college has expanded its academic offerings to include diverse undergraduate and postgraduate courses.

These include a Bachelor of Business Administration (BBA) program, as well as Bachelor of Technology (B.Tech) programs in Artificial Intelligence (AI), Machine Learning (ML), and Computer Science Engineering (CSE). The college also offers integrated programs like BCA-MCA, designed to enhance students' career prospects.

Accredited by the Council of Architecture (COA) and the All India Council for Technical Education (AICTE), MBS College ensures high academic and professional standards. The college is working towards becoming a full-fledged university, reflected in the ongoing development of its 2-acre campus. The campus will feature state-of-the-art infrastructure, including new academic blocks, technology labs, a duplex library, and a large auditorium. Additionally, facilities such as indoor sports spaces, recreational areas, and a unique indoor parking facility will enhance student life.

MBS College places significant emphasis on practical learning through workshops, guest lectures, site visits, and industry-aligned curriculum. These initiatives bridge the gap between academic knowledge and real-world application, preparing students for successful careers. The institution's consistent focus on excellence has earned it an A+ rating from the SFRC and recognition from publications like India Today and Silicon India. With its modern infrastructure and holistic approach to education, MBS College offers students a well-rounded and progressive academic experience, making it an attractive choice for those seeking a comprehensive education.

ISBN 978-93-342-4408-3

Shri Gulshan Kumar Magon

Chairman
MBS College
New Delhi

CHAIRMAN'S MESSAGE

It gives me immense pleasure to present this ISBN publication, a compilation of scholarly research papers contributed by academicians, professionals, and students during the National Conference on **"Advanced Architectural and Planning Practices – Bridging Innovation, Sustainability, and Design".** This body of work reflects not only the intellectual rigor and academic commitment of its contributors but also the progressive vision that MBS College upholds.

At MBS College, we remain rooted in our core values of nurturing the Mind, Body, and Soul, fostering a holistic educational journey that encourages critical inquiry, creative expression, and responsible innovation. Since our inception in 2009 with a modest intake of 40 architecture students, we have grown into a dynamic institution, now accommodating 120 students annually and recently expanding our academic horizon with the introduction of BBA and BCA programs.

This growth is a testament to the collective dedication of our faculty, staff, and students, and the unwavering support of our stakeholders. More importantly, it reflects a shared belief in the transformative power of education and its potential to shape a sustainable and equitable future.

The theme of this conference – Bridging Innovation, Sustainability, and Design – resonates deeply with the challenges and opportunities that lie ahead in the field of architecture and planning. As we confront the realities of climate change, urbanization, and resource scarcity, it is imperative that our solutions not only push the boundaries of design thinking but also remain grounded in sustainability and social responsibility.

The research presented in this volume is a significant step in that direction. It showcases a spectrum of innovative ideas, contextual studies, and critical analyses that together pave the way for more inclusive, sustainable, and forward-looking built environments.

As we prepare for a future enriched by new infrastructure, enhanced academic resources, and a growing community of learners, I remain confident that the ideas and collaborations born out of this conference will contribute meaningfully to both academia and practice.

I congratulate all the contributors and extend my sincere appreciation to the organizing team, faculty members, and participants who made this conference and its publication a success.

Let us continue to build not only with bricks and mortar, but with ideas that endure and values that inspire.

Shri Gulshan Kumar Magon

ISBN 978-93-342-4408-3

Prof. V. K. Bugga

Advisor
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ADVISOR'S NOTE

"Nature to be commanded, must be followed"

In this proceedings book we are discussing Advanced Architectural and Planning Practices. Here the key word before us is 'Advanced Practices'. Planning is a continuous process and it keeps changing from time to time, place to place and culture to culture. Trends are changing not just in Architecture and Planning but in our daily lifestyle as well. Trends change in fashion clothing, eating habits and social systems. Joint families to nuclear families. Thereby the Haveli concept of apartments. Technology today has set new trends in our living style transforming the environment of our habitat. Accommodating high densities in erstwhile low density areas due to rapid urbanization. Among all these changing trends, the perspective of architects and planners has also changed. WE, as architects, need to keep pace with the changing technology, changing human behavior, cultural impacts on a global level, more exposure and more interactive communication systems. An architect must study and understand the implications of these changing trends for a realistic design approach. In the past also, we as architects and planners have been addressing these changes at the societal, community and national levels to give our citizens a congenial environment.

The tools of design have changed, the thought process of an architectural concept and its three dimensional vision has changed its language and expression as well. Technology in the field of construction has accomplished new laurels by building structures in an unprecedented short time. There is a competition at the global level as to how soon a multistoried structure could be built.

But, as I said initially, an architect has to study and comprehend these new trends to design in the present. And while doing so, we must not forget the society- its heritage, cultural and social values. There is a lot of discussion these days on the subject of Vastu- Vastu Shastra, Vastu Mandal, Vastu Purush and so on. These are not just placement of spaces and their orientation in a particular direction of a building or a complex. It also has cultural, social and scientific angles—the values most important to cultivate even when going global in design synthesis. A building is just a block of walls and spaces if it does not have an intrinsic feeling of belongingness to the society and its cultural heritage. The essence of vernacular in terms of material. Traditions and heritage together build the soul of the structure.

So, the task today, for the generation next—that is going to be responsible to showcase India in the competing practices of architecture the world over—is as to how it can design every structure which is socially, culturally, environmentally and functionally viable and acceptable to the user.

As you have already read in Design theory that a building has a direct impact on the mind and personality of its user, so let us use the new trends in technology, the style of construction and building materials to create built masses which are cohesive and sensitive to the human psyche, to create spaces that are not just accurate in design but also have the essence of life and belongingness, an aura of indigenous comfort.

Computers, networks, software and more and more digitalization has totally revolutionized architectural education as well as practice. In today's world of global warming, environmental pollution, and growing population, the task of the architects and planners has become more important and relevant since they shoulder the responsibility of creating liveable, healthy and environmentally sensitive built spaces. And the new trends- as we call them—in the field of architecture and planning should be used to serve us to achieve the challenging goals and objectives of designing a more humane environment in future.

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The Problem

Urbanisation is seen as a phenomenon of progress of civilization. Especially in the context of a developing nation like India, it is the most important phase with almost all the cities and towns of all levels aspiring for a better environment. There is a race towards acquiring new systems, new technologies and new horizons while attempting to keep pace with the process of urbanization.

The big cities are crowded with people, aspiring for jobs and better career prospects. With an increase in the status, residents are looking for better areas to live in. But there is a section of the population that is yet to acquire a shelter. The metropolises are the places of contrast. They are places of plenty and scarcity. They are the places of affluence and poverty as well. But we ought to seek a balance. Every citizen must breathe. He must be allowed to live in peace, in comfort. He must get water to drink, wash and cook. He must get electricity to light his home. He must get all that is required to fulfil his biological needs.

This raises the question of affordability. So we classify our population- very cleverly- on the basis of the economic status of the citizens. If A can afford all these, B shall be satisfied with some of them. But no. Such a synthesis does not work in an urban system. Facilities cannot be denied. Everyone must get everything. And for that we shall have to devise means, modes and methods to distribute to all that is available.

So, let us take stock of the things. For a shelter in the city, one needs- a roof with adequate supply of water, electricity, heat, light, ventilation, sanitation, recreation and freedom from pollution. This is where the role of planners- the plan makers, the bureaucrats- the decision makers and the politicians- dictates the policy guidelines.

Since we are dealing with the affairs of a city- a metropolis, and to be more precise an urban agglomeration comprising of the national capital and the region around, we shall focus on the problems related to the planning and implementation of the city vis-à-vis the innovations needed and already taken up by the individuals and the concerned authorities together in this direction.

Water Supply

Water is one of the most essential elements for survival of human beings. Earliest settlements in the history of civilization were found by the side of water bodies. Water bodies containing potable water can be identified as a river, a pond, a lake, a well etc. But now, in an urban area we use treated water, be it from river, tube well or otherwise.

But water from the treatment plants- piped water supply, does not cover entire urban areas of the capital. Population staying in unauthorized colonies and JJ clusters mostly depend upon hand pumps and tube wells- with water taken directly from the ground- without treatment. In Delhi it is mandatory to seek prior approval from the Central Ground Water Commission for every bore-well. This is to check the fast reduction in the ground water level. In the areas devoid of any piped water supply and planned sewage system, there is danger of untreated water percolating down the ground into the soil and ultimately polluting the subsoil water as well. Such water if used for drinking and cooking, may pose serious health hazards and therefore needs to be attended to on priority- especially in unauthorized colonies where infrastructure is not well developed or underdeveloped

To augment the level of ground water, the concept of rain-water harvesting is gaining momentum. A rain-water harvesting plan is now mandatory for any large building project. There is stress on providing soft surfaces while drawing the landscape plan so that more water percolates down the subsoil.

Electricity

India is now advanced enough to supply electricity to all areas including villages. But researches are on to find much better, simpler and cheaper methods to produce electricity. Electricity through wind mills in wide open areas is a welcome step forward. But converting solar energy to electricity is the most economical. Solar panels on the rooftops is the new trend in environment friendly technique for production of electricity.

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Biomass and Waste Utilisation

Lot of fuel in the form of Liquid Petroleum Gas, coal,kerosene, wood etc including electricity is consumed for cooking in the household and for other heating appliances. All this is ultimately leading to the consumption of resources and making them costlier with the passage of time. Global warming is the macro level phenomena as a result of such excessive fuel consumption.

At the same time, metropolitan areas like Delhi have the problem of disposal of solid waste in the city. The process of filling up low-lying areas with garbage, also has its limitations. Researches in the environmental conservation and management have suggested that no such landfill site be utilized for habitation purposes as multiple poisonous gases are emitted through the process of decomposition of garbage and thus it is harmful to human beings. But now with the advent of new technologies, compost plants are being installed which will not only consume garbage without spilling over large tracts of land but will also provide alternative fuel for consumption for various domestic and commercial purposes.

Building Material

Modern technological advancements and research have brought in the options for the correct use of the building material. CBRI and other such organisations bring out research on the optimum, adequate and indigenous building materials for low cost housing and have many positive experiments and examples to suggest effectiveness of the intrinsic qualities of building materials. Correct choice of building materials, their availability locally and application of design with due regard to the climatic conditions can considerably bring down- not only the cost of the building- but also the recurring cost of the use of artificial energy techniques and tools.

A good ventilated plan of a house considering the periodic wind direction and solar movement in the area may keep the house airy as well as hygienic making the environment more healthy and habitable. It is important to assess the behavioural pattern of these materials and the combinations of them as they come together in the architectural/ engineering design. An environmentally friendly house can, in due course of time, prove to be much cheaper to live in as compared to a conventional urban dwelling unit.

Transportation

Transport has been an important parameter for urban as well as industrial growth for towns, cities and nations. Urban planning has been reforming the plans for cities with the passage of time. Linear towns along the road/ rail routes; garden cities in response to industrial pollution; satellite towns around major work centres- the metros, decentralization of work centres, and so on. Now with the expansion of the railroad network and increasing migration to cities, the concept of ToD, Transport oriented development has emerged considering excessive traffic on roads and time spent in travelling. These are concentrated work cum residential areas with institutional and commercial facilities in walking distance. A good concept but difficult to make it functional.

Environmental Concerns

An answer to the problem of increased land requirements for habitation, production, circulation and recreation has been a specialization of Land Use Planning. The landscape has been subdivided into mutually exclusive or conflicting land use areas for the production of maximal amounts food, timber, water and energy requirements of a high technological standard. The necessity to introduce new land use types and methods has led to the implementation of powerful and quickly superseded ‘stop gap’ measures provided by science and technology.

1. Reclamation of land over water
2. Vertical expansion and over intensification
3. Tube railways for mass transportation
4. Artificial conditioning of atmosphere
5. Increasing number of metropolises and megalopolises.

All above measures are in contradiction to the natural ecosystems and hence they are in a process of

ISBN 978-93-342-4408-3

destroying the existing eco-structures. Apparent consequences are visible in different ways;

1. Over concentration of population
2. Heavy concentration of industries creating inter-regional disparities, massive flow of migrants, air and water pollution
3. Inadequate housing, creation of slums
4. Pressure on utilities and services
5. Spiraling land values
6. Lack of sufficient open spaces
7. Absence of recreational facilities

Now, having seen the undesirable consequences of the present day planning theories, policies and practices, the importance of ecological planning emerges by itself. And before evolving a strategy for planning, the eco-structures are to be studied with maximum understanding of their natural behavior. A detailed study of the environment- the natural environment- its constituents that play a vital role in creating man made structures above- along with their threshold analysis- the extent to which they could be exploited, is essential to save the environment or in other words to create a more humane environment.

Following is the list of probable essential environmental parameters that require an in-depth study and analysis before making them vulnerable in the hands of builders.

Climate & micro-climate

Prevailing wind direction
Still zones
Zones of greater solar insulation
North facing slopes
South facing slopes
Air pollution
Noise pollution

Geology- Bedrock & Economic

Types of rocks
Engineering properties of rocks
Economic minerals
Gravel pits
Clay pits
Building stones

Physiography

Slopes
Ridges
Promontories
Flood plain
Lowland terraces
Upland terraces
Deep valleys
Flat valleys
Knolls
Escarpments
Visual bowls

Soils

Soil types
Engineering properties of soil
Erodible soils
Depth to bedrock
Depth to seasonal water table
Agricultural soil

Vegetation

Forest by types
Evergreen & deciduous
Isolated strands of different tree species
Farmlands
Orchards
Nurseries
Herbaceous areas
Scrub areas
Old fields
Important ecological associations

Wild Life

Terrestrial and aquatic
Mammals, birds, fish etc.

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Hydrology- Surface

Streams, lakes, ponds, springs, reservoirs, wells etc.
Floodplain
Floodplain terraces
Drainage lines
Stream order
Freshwater marshes
Salt water marshes
Swamps and low-lying areas of poor drainage
Areas of tidal inundation
Aquifer outcrop areas
Aquifer recharge areas
Surface water quality & quantity

Hydrology- Subsurface

Aquifers
Depth to water table
Water table fluctuations

We need to understand the behavior and psychology of all these parameters if we want a disaster free environment for the generations to come.

Material progress marks peaks of civilization, but the culture of people is measured by relative social values and the purpose that directs human progress.

Prof. Viresh Kumar Bugga

ISBN 978-93-342-4408-3

PREFACE

In a world increasingly defined by environmental uncertainty, rapid urbanization, and digital disruption, the disciplines of architecture and planning carry a profound responsibility—not just to shape space, but to cultivate meaning, identity, and harmony. The National Conference on “Advanced Architectural and Planning Practices: Bridging Innovation, Sustainability, and Design”, hosted by MBS College on July 10th and 11th, 2025, is both a response and a reflection—a gathering of minds committed to reimagining our built environments with conscience and creativity.

“We shape our buildings; thereafter, they shape us”, These words by Winston Churchill serve as a poignant reminder that every decision in design ripples outward—affecting not just materials and forms, but culture, community, and the collective psyche. This conference embraces that ripple effect, inviting critical inquiry into the practices, technologies, and philosophies that will define the cities of tomorrow.

Participants in this forum bring diverse voices to the table—thought leaders in ecological design, pioneers in technological innovation, keepers of cultural wisdom, and educators reimagining pedagogy. Together, we explore not just the **how**, but the **why** of architectural thinking. From Vastu principles to AI-enhanced design tools, and from vernacular wisdom to virtual environments, each theme represents a confluence of past, present, and future.

Echoing the ethos of Vitruvius, who believed that architecture must embody “**firmitas, utilitas, venustas**”—strength, utility, and beauty—this conference aspires to add a fourth pillar: **“consciousness”**. As Lao Tzu once said, *“The way to do is to be.”* We believe meaningful innovation stems not just from doing more, but from being more attuned—to nature, to human need, and to the cultural fabric that binds us.

To all contributors, reviewers, and participants, we express our sincere appreciation. May these proceedings serve not just as documentation, but as inspiration. And may this conference reaffirm our collective responsibility to shape places that are not only smart, resilient, and just—but also **soulful**.

“Design is not just what it looks like and feels like. Design is how it works.” – Steve Jobs

“A great building must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable.” – Louis Kahn

As we journey through the dialogues and discoveries housed within these proceedings, may we be reminded that architecture is not only about constructing spaces, but about nurturing life within them. Each brick laid, each plan drawn, is a testament to our values and aspirations. This conference is a collective affirmation that design, when guided by empathy, knowledge, and vision, holds the power to heal, to connect, and to transform. May the ideas shared here continue to echo beyond these pages—into studios, classrooms, communities, and cities—fueling a future that is not only built, but beautifully *becoming*.

Let us design not only with our hands and minds, but with our hearts.

ISBN 978-93-342-4408-3

Editorial Team

Ar. Toshi Sharma, Associate Professor

Ar. Toshi has over 17 years of techno-functional experience in teaching, architecture, and urban planning. She has worked with esteemed institutions and firms such as USAP-GGSIPU, ASCI-Hyderabad, and Egis India. Committed to research-led teaching, she actively engages with students, incorporating feedback and developing innovative learning approaches. She has played a key role in curriculum review, quality assurance, and academic enhancement. With significant experience in urban planning projects, she has been involved in project completion, scheduling, stakeholder workshops, and government consultations. At MBS College, she integrates her expertise in architecture and urban planning to provide students with a well-rounded and practical education.

Ar. Shubhi Khare, Assistant Professor

Ar. Shubhi Khare is an architect with a deep passion for urban design, housing development, and architecture. Her extensive involvement in urban design projects reflects her commitment to creating impactful and sustainable spaces. With hands-on field experience, she has developed a strong understanding of practical design implementation, ensuring functionality and innovation in her work. She combines creativity with technical expertise to develop solutions that enhance the built environment. At MBS College, she strives to inspire students by integrating real-world challenges into architectural education, fostering a deep understanding of urban design principles and their role in shaping communities.

Ar. Kriteeka Sharma, Assistant Professor

Ar. Kriteeka Sharma is a practicing architect and landscape architect with experience in commercial, residential, and institutional projects. She has a strong passion for both historical and modern landscapes, allowing her to blend traditional elements with contemporary design sensibilities. With expertise in spatial planning, she focuses on creating functional, sustainable, and visually appealing environments. Her keen interest in landscape architecture drives her to explore innovative approaches to outdoor space design, ensuring harmony between built and natural environments. Dedicated to academia, she strives to inspire students by bridging theoretical knowledge with practical applications. At MBS College, she aims to cultivate a deeper appreciation for landscape architecture, encouraging students to think critically and creatively about the spaces they design.

Ar. Divesh Wadhwa, Assistant Professor

Ar. Divesh Wadhwa is an architect and designer with experience in commercial and residential projects. His expertise lies in sustainability, interior design, space planning, and urban design. With a strong analytical mindset and a commitment to perfection, he approaches architecture with a balance of logic and creativity. Passionate about sustainable practices, he has conducted research on eco-friendly materials and their properties, integrating this knowledge into his academic and professional work. His enthusiasm for exploration and innovation drives his teaching, encouraging students to think critically and design responsibly. At MBS College, he aims to inspire future architects by combining technical proficiency with a sustainable and thoughtful design approach.

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Shaping Experience and Behavior: The Impact of Streetscape Elements on User Perception and Consumer Engagement in Commercial Streets of Delhi.

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Abstract

Commercial streets are important components of urban areas. They have a high concentration of businesses, shops, and retail establishments, making them bustling and vibrant areas of a city or town. Outdoor areas are symbolised by streets. For practical, social, and recreational purposes, people rely on the streets for travel, shopping, play, social connection, and even relaxation.

In the context of Delhi—a city marked by a diversity of architectural styles, economic activities, and cultural textures—this research investigates how the physical configuration and design of streetscapes influence user perception and consumer engagement in key commercial areas.

This study looks at how the physical elements of streetscapes influence user perception and consumer engagement. By emphasizing components like pavement quality, clear signage, street lighting, greenery, facade treatment, public amenities, and shop fronts, the study investigates how these elements work together to influence perceptions of comfort, safety, accessibility, and aesthetic appeal as well as the cognitive behavior of the consumer.

The study uses a mixed-method approach that includes behavioral observations, structured surveys, and spatial audits like on site observation and photographic documentation, throughout important commercial zones in Delhi. This study fills a significant void in Indian urban studies by empirically connecting spatial form to behavioral consequences. It also provides practical advice for improving the consumer experience in Delhi's commercial public spaces.

Introduction:

"Think of a city and what comes to mind? It's Streets. If a city's street look interesting, the city looks interesting; if they look dull, the city looks dull".[1]

Streets are the public spaces of the cities, considered as one of the basic units of urban areas. According to Merriam Webster Dictionary meaning it is- a thoroughfare especially in a city, town, or village that is wider than an alley or lane and that usually includes sidewalks.[19] The streets are the lifeline and foundation of the communities and urban economies. They account for more than 80% of all public space in cities and have the potential to boost business activity, serve as a front yard for homes, and provide a safe location for people to navigate, whether on foot, by bicycle, automobile, or public transportation. [2] The vitality of urban life necessitates a design strategy that takes into account the multifaceted function of streets in our cities. Global street design guide explains that many times it is misconceived as a two dimensional surface for the vehicle movement from one place to another. But in fact, it is a multidimensional space consisting of multiple spaces and structures, stretching from one property line to another. Streets must complete a complicated variety of tasks to meet people's demands as locations to live, work, and move around in.[3]

Streets facilitate transportation, social contact, and commerce by tying people and places together.[4] Different issues are addressed and streets take on a variety of forms across the globe; these variations contribute to the identity and sense of place of cities. [5, 6]

Streets are regarded as public spaces, especially areas like dense neighborhoods that lack open spaces; their streets constitute a place for social interaction with different sets of activities. Streets in developing countries, as described by Appleyard are be significantly more complex than those in the advanced world since they feature more mixed forms of transportation and heterogeneous usage.[7] Streets display local,

ISBN 978-93-342-4408-3

cultural, religious, and social activities, which determine the street's vibrancy, originality, and success as a public area. Streets are formed with the settlement pattern of a neighborhood. As suggested by scholars in a variety of urban studies-related subjects, public life can be supported, facilitated, and promoted by the urban spaces like plazas, streets, parks.8]

What is Commercial Street?

Retail stores, restaurants, service providers, and street sellers are concentrated along a commercial street, which is a public urban road largely used for economic activity. These streets integrate business, pedestrian traffic, and public life, making them essential social and economic centres. Commercial streets are open-air, connected with urban infrastructure, and frequently represent the local culture, in contrast to enclosed shopping malls.

According to Kang the commercial strip serves as a community space in addition to being a place for basic shopping, which gives the area vitality.[9] People rely on streets for a variety of purposes, including travel, shopping, play, meeting and interacting with others, and even relaxation. [1]

The Importance of Streetscapes in Urban Commercial Areas

In commercial districts, streetscapes are the integrated layout and practical components of urban streets—act as crucial frameworks that influence social interactions, cultural identity, and economic vitality. Streetscapes have a direct impact on consumer behaviour, company performance, and urban sustainability in vibrant cities like Delhi, where contemporary retail corridors mix with historic bazaars.

Regardless of their varied sizes and styles, the basic elements that make up every urban street are lanes, pavements, and streetscaping. The demands of users should be taken into consideration when designing different roadway features. All user classes, ages, and genders should be able to use it.[10]

This study attempts to create a theoretical framework that may be used to redesign commercial streets based on user perception and consumer behavior. It comprises an in-depth assessment of related literature as well as observational research.

Literature Review:

Commercial streets frequently benefit from a combination of retail, office, residential, and entertainment uses. The integration of these various functions creates a dynamic and vibrant environment in which people can live, work, and engage in recreational activities on foot. Since the last few decades it has been suggested that mixed use neighborhoods are a more desirable pattern of development. Jacobs work 'The death of Great American Cities' highlights the value of high-density neighbourhoods, diversified land use, and encouraging public spaces in creating a vibrant and convivial environment. [1] According to various other authors it is being found that by mixing various land uses the overall environment can be more vibrant, safe, and sustainable.. According to shopping behavior research, people go shopping spend time with their pals, look around and people-watch, and walk about in addition to the primary activity of acquiring goods and services. Social affiliation and interaction, sensory stimulation, and other leisurely activities have been identified as important and basic motives for shopping behavior.[12] Human characteristics are recognized as the key that supports for creating a good urban environment. As a result, the individuals who utilize and interact with the urban space can rate it as good or poor.[13]

Physical Characteristics:

Architectural features, materials and traditions, building-landscape relationships, history, and economy all have an impact on the character of streets. The purpose of physical qualities is to make the street recognisable, prominent or visible.[14]

Study by Balasubramanian explored the relationship between the environmental and aesthetic qualities of urban commercial streets, emphasizing the importance of open spaces for community interaction. The findings highlighted that elements like facade design, color, maintenance, and vegetation significantly

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influence user's walking preferences in commercial street, demonstrating the need to focus on these aesthetic attributes to enhance street vitality.[15] By examining the relationship between retail space attributes and consumer behaviour, the study by Lian, H., investigated the spatial vitality of retail spaces in Zhuangli Commercial Street, China. The study measured the effect of shop window visibility and spatial arrangement on shop visits using visibility graph analysis and space syntax theory. The results showed that improved spatial connectedness and increased visibility have a good impact on the vibrancy of retail spaces, offering guidance for improving the design of commercial streets to increase customer interaction.[16] According to the study by Shamsuddin, it underlined how crucial environmental comfort, safety, and accessibility are when designing streets. It emphasized how streets must be kept clean, clear of clutter, and safe for pedestrians in order to serve all users, including the elderly and disabled.[17]

Helmy and El Hama speak directly to the topic of "Humanising Commercial Streets as a Tool for Social Sustainability." This essay makes the case that establishing more commercial avenues with a human focus promotes societal sustainability.[18]

According to the literature, lively, prosperous commercial streets are the result of careful urban planning that puts walkability first, takes into account a variety of elements that affect performance and appeal, and eventually strives to build livable, sustainable, and human-centered public areas.

Broad Parameters	**Indicators**	**Reference**
Urban Design & streetscape elemen	Street Layout & Sidewalks	Kethusha K (2019), Ewing, R., & Handy, S. (2009), Shatha Mahmoud Al ODAT(2021), Mehanna (2019)
	Street Furniture	Mehta, V. (2014)
	Nodes & Open Spaces	Gehl, J. (2011).
Architectural & Aesthetic features	Building façade	Balasubramanian (2022), Xuanming Mu (2024)
	Shop front or Personalization	Mehta, V. (2010), Haitao Lian(2023)
	Visual Appeal	Abusaada, Hisham; (2021)
	Shade	Sami Al-Obeidy Musaab (2018)
Environmental & Sensory Factors	Green elements	Shatha Mahmoud Al ODAT(2021), Mehanna (2019)
	Noise & Odour	
	Air pollution/ ventilation	
	climatic Condition	
	Lighting Conditions	
Functional & Mobility Aspect	Walkability	Shatha Mahmoud Al ODAT(2021),
	Accessibility	Hazhar Muhammad Khder (2016)
	Parking	
Retail & Commercial features	Retail density	
	Retail attribute	Yeankyoung Hahm(2017)
	Retail shop layout / Store envir	Haitao Lian(2023)
Safety & Security features	Surveilliance/ visual Connectio	Hazhar Muhammad Khder (2016)
	cleaniness / maintainance	

Table 1: Identified broad parameters from the literature, Source; Author

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Selected Site Study:

One of the liveliest and busiest business districts in South Delhi is Lajpat Nagar. Originally built in the 1950s to house refugees during the Partition, it has grown into a popular shopping destination renowned for combining modern and traditional retail experiences. The main commercial district of the region, which is separated into multiple blocks, is Lajpat Nagar Central Market (Lajpat Nagar-II), which is well-known for its textiles, clothing, accessories, home items, and street food.

Criteria for selecting Lajpat Nagar as a site study is its Location (Connectivity, accessibility, availability of public transport), Functional Diversity (Variety of retail services and economic goods) , Cultural and social significance as a shopping hub for locals and tourists.

Study of the site:

The site is firstly observed by using walk-by observations, where the number and location of persons as well as the activities they were involved in were noted. To find out how people interacted with the street's features, unstructured direct observations were employed. A list of activities are prepared and those activities are correlated with the physical characteristics of the commercial street at Lajpat central market.

Figure 1: View of the Street Studied

The number and location of persons as well as the activities they were involved in were noted using walk-by observations. The duration of stay of individuals at different block segments was documented through structured direct observations.
To find out how people interacted with the street's features, unstructured direct observations were employed.

Physical, sensory, and sociocultural factors interact dynamically to define Lajpat Nagar's commercial streetscape, which in turn affects user experience and customer engagement. High foot traffic, especially on weekends and during festive seasons, has a significant impact on the area's walkability and pedestrian flow, creating crowded, narrow pathways where pedestrians must negotiate a mix of shoppers, sellers, and cars. Although it adds to the lively ambiance, this congestion frequently makes it difficult to move about, which affects the accessibility and comfort of shoppers. Perception is greatly influenced by visual and sensory inputs, and a multimodal retail experience is created by lively shopfronts, brilliant textile displays, and busy street food vendors. But the sheer volume of visual clutter, from conflicting signs to chaotic vendor arrangements, can also cause sensory overload, which can affect where customers focus their attention and how long they stay.

With a blend of modern and classic retail spaces providing a range of aesthetic charms, shopfront and street furniture design also enhances the user experience. However, there are fewer rest chances due to inconsistent signage, a lack of seating, and inadequate shade, which could cut stay time. The coexistence of formal and informal shopping, where established stores and street vendors coexist and create a vibrant but frequently chaotic streetscape, is another distinguishing characteristic.

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In addition to encouraging engagement, the negotiating culture and direct connections between customers and vendors provide the shopping experience a social component that also raises concerns about accessibility and spatial justice. Last but not least, social and cultural exchanges, such as community-driven business and seasonal sales, support Lajpat Nagar's reputation as a bustling business district where the streetscape serves as both a social and retail venue. These factors work together to influence how consumers view, traverse, and interact with the market, offering opportunities and difficulties for commercial planning and urban design.

Conclusion:

The results show that in order to improve functionality without reducing the market's natural liveliness, balanced urban interventions are required, such as enhanced street furniture, pedestrian infrastructure, and vendor management. To find more general trends in streetscape design and customer interaction, future research can compare Delhi's commercial streets. In the end, Lajpat Nagar serves as an excellent example of how commercial streetscapes are more than just places for transactions; rather, they are intricate ecosystems where human behaviour, culture, and design converge. As such, it offers important insights for retailers, legislators, and urban planners who want to establish more sustainable and interesting marketplaces.

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ISBN 978-93-342-4408-3

Human-Centered Design: Integrating Culture, Community, and Architecture – A Case Study of Khan Market, New Delhi

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Abstract

This paper investigates the role of Human-Centered Design (HCD) in creating inclusive and contextually responsive urban spaces, using Khan Market in New Delhi as a case study. It explores how architectural and urban interventions grounded in empathy and community engagement can address design challenges while celebrating cultural identity. Through spatial analysis and user behavior observations, the study identifies gaps in accessibility, comfort, and engagement. Proposed strategies include improving walkability, introducing micro-public spaces, and integrating cultural storytelling. The findings underscore the potential of HCD to regenerate urban environments while preserving their historical and social character.

Keywords: *Human-Centered Design (HCD), Community Architecture, Cultural Integration, Urban Regeneration, Khan Market, User Experience in Urban Spaces, Placemaking, Contextual Design, Inclusive Design, New Delhi Urbanism*

Introduction

Human-Centered Design (HCD) is a design philosophy that prioritizes the needs, experiences, and aspirations of people in the creation of spaces. In the context of architecture and urban design, HCD goes beyond aesthetics to consider social dynamics, cultural narratives, accessibility, and emotional well-being (Refer to Figure 1). As cities rapidly evolve, the need for inclusive, empathetic, and community-driven design becomes increasingly critical. This paper focuses on Khan Market in New Delhi, a culturally significant commercial district, as a lens to explore how HCD can enhance the everyday experience of urban users while preserving heritage and fostering community.

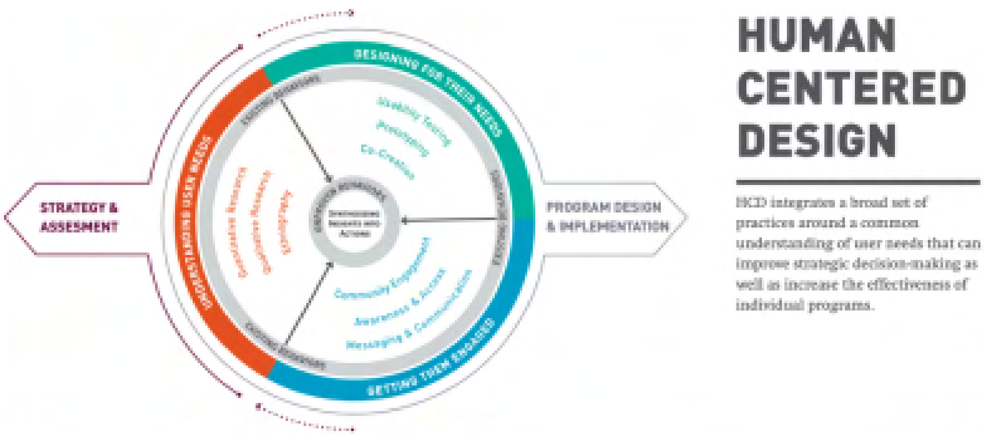

Figure 1 . The Concept of Human-Centered Design
https://blog.cedim.edu.mx/noticias-cedim/human-centered-design/

Theoretical Framework and Literature Review

HCD originated in the field of product design but has been adapted by architects and urbanists to create spaces that respond to human behavior and contextual realities. According to Don Norman, human-centered products and spaces must be usable, equitable, enjoyable, and sustainable. Urban theorists like Jane Jacobs have emphasized the importance of lively streets, social interactions, and the human scale in city planning. In the Indian context, placemaking has roots in traditional bazaars and chowks, which naturally blended commerce, culture, and community. This research draws from these theories to analyze Khan Market's potential as a human-centered space.

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Understanding Khan Market: History and Present Context

Established in 1951 to provide economic opportunities to refugees of Partition, Khan Market has evolved into one of India's most upscale and iconic shopping destinations. Despite its elite transformation, the market retains a layered identity, housing old bookshops, food joints, salons, designer stores, and street vendors. It functions as a hybrid space where modern consumerism meets cultural nostalgia. However, increasing commercialization has led to design challenges such as congestion, lack of pedestrian comfort, inadequate public amenities, and poor accessibility for elderly and disabled individuals.

Spatial and User Analysis

The urban design analysis conducted earlier in the semester revealed a complex spatial configuration.

- Khan Market comprises a mix of formal and informal spatial arrangements, where narrow walkways, shopfront encroachments, and irregular setbacks create a cluttered environment. (Refer to Figure 2)
- The central spine, while heavily trafficked, lacks defined pedestrian movement channels and fails to offer a sense of orientation or rhythm.
- Key entry points are visually blocked by vehicles or kiosks, reducing permeability and ease of navigation. (Refer to Figure 3)
- User profiling based on site observations and informal interviews revealed a diverse user base: Affluent shoppers, expatriates, students, local residents from nearby colonies, and daily wage workers.
- Each group engages with the space differently—while shoppers seek visual appeal and ease, workers require resting zones and functional infrastructure.
- The elderly and differently-abled often struggle with uneven surfaces, steps without railings, and lack of accessible toilets.
- Moreover, there is an evident absence of gender-inclusive facilities, especially for women looking for safe and comfortable waiting or pause zones.
- Despite the cultural vibrancy of the area, the physical environment restricts spontaneous community interactions due to inadequate seating, shading, and interactive public elements.

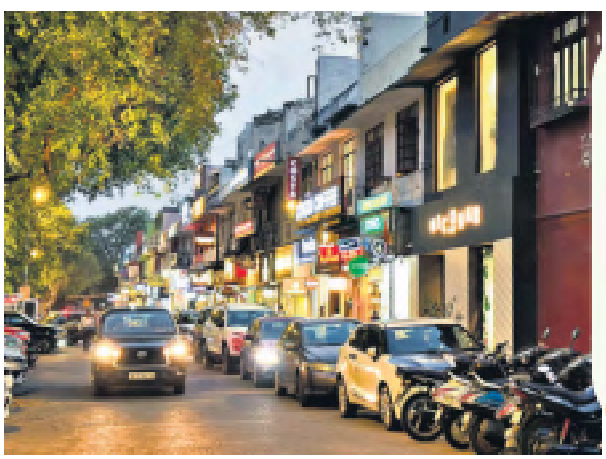

Figure 2. formal spatial arrangements ~Author

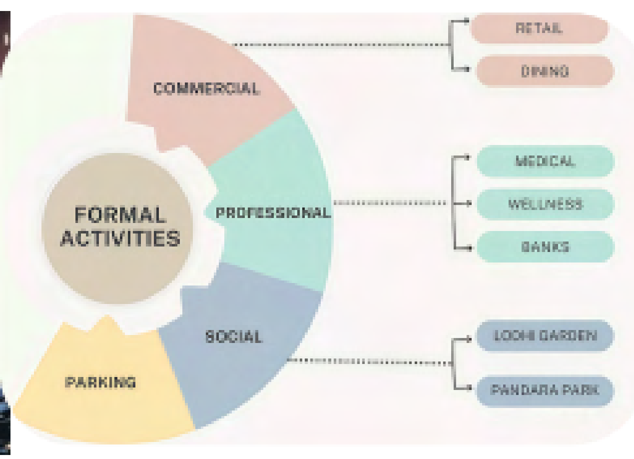

Figure 3. visually blocked by vehicles ~Author

Human-Centered Interventions:

Strategies for Improvement To make Khan Market more inclusive and people-centric, the following human-centered design strategies are proposed:

- **Cultural Storytelling through Design:** Incorporate local art, murals, and interactive storytelling elements along blank walls and entry zones to celebrate the heritage of Khan Market. These can

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include digital kiosks with archival photos, quotes from Partition refugees, or QR-coded walking tours.

- **Barrier-Free Movement:** Replace uneven pavements with continuous tactile flooring (Refer to Figure 4) and introduce low-gradient ramps, railings, and widened footpaths to ensure that the elderly, children, and people with disabilities can move independently and safely. (Refer to Figure 5)
- **Shaded Pause Points:** Install lightweight tensile structures or pergolas with climbing greens to create shaded pockets at intervals. Under these can be placed low-maintenance benches, charging docks, water dispensers, and dustbins for rest and utility.
- **Gender-Inclusive and Accessible Toilets:** Renovate existing public toilet blocks with universal design principles. Add family-friendly restrooms and child-changing areas to enhance inclusivity. (Refer to Figure 6)
- **Vendor-Friendly Zones:** Designated semi-permanent kiosks for local flower sellers, tea stalls, or handicraft vendors can be integrated into the layout to legitimize informal economies while organizing circulation flow.
- **Dynamic Signage and Wayfinding:** Introduce a cohesive, bilingual signage system across the market with clear icons, directions to amenities, and emergency contact points. Use warm lighting and reflective materials to enhance visibility at night.
- **Community-Led Micro-Events:** Introduce flexible nodes (open plazas or wide setbacks) that can host weekend markets, book fairs, or musical evenings to foster a sense of shared cultural space. (Refer to Figure 7)

These interventions aim to address both physical and emotional needs, ensuring that Khan Market evolves into a more welcoming, accessible, and engaging urban commons.

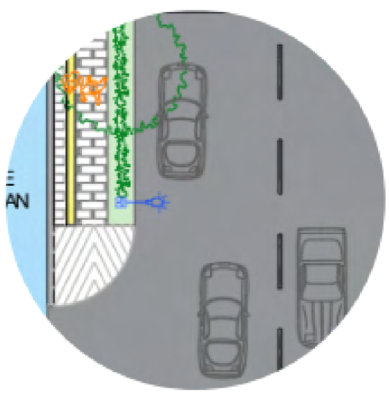

Figure 4. Inclusive design (ramps) ~Author

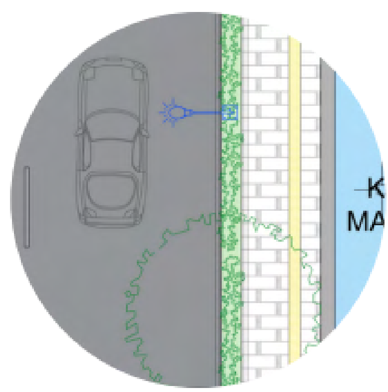

Figure 5. Yellow tactile tiles ~Author

Figure 5. Gender-Inclusive and Accessible Toilets ~Author

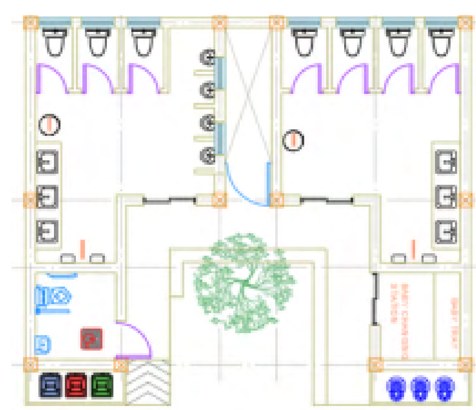

Figure 6. Community-Led Micro-Events: ~https://i.pinimg.com

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Community and Contextual Design Approach :

A truly human-centered approach in architecture requires deep sensitivity to local context— social, cultural, and climatic. Khan Market's design interventions must respond not only to spatial constraints but also to its distinct character as a post-Partition commercial enclave. Using locally available materials, referencing traditional Indian architectural vocabulary, and working with existing textures can help retain the place's historical authenticity. Architectural gestures such as shaded arcades, permeable façades, and low-height built forms maintain human scale while promoting comfort (Refer to Figure 7). Engagement with the community —shopkeepers, workers, and regular visitors (Refer to Figure 8) —should be part of an iterative design process. Their feedback can guide the evolution of spatial strategies that are inclusive, respectful, and long-lasting.

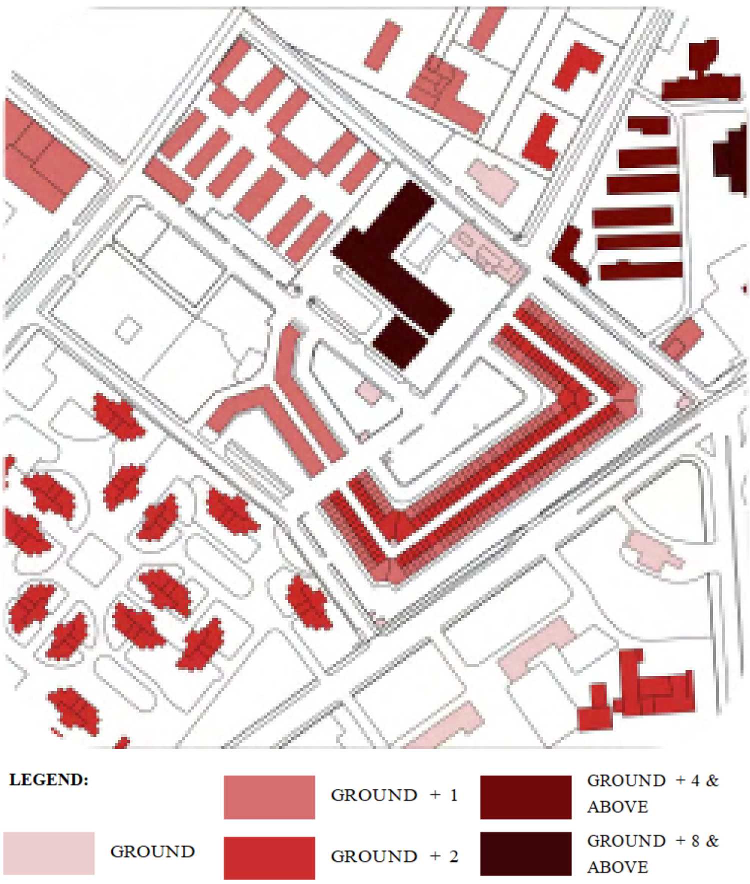

Figure 7. Built-Form ~Author

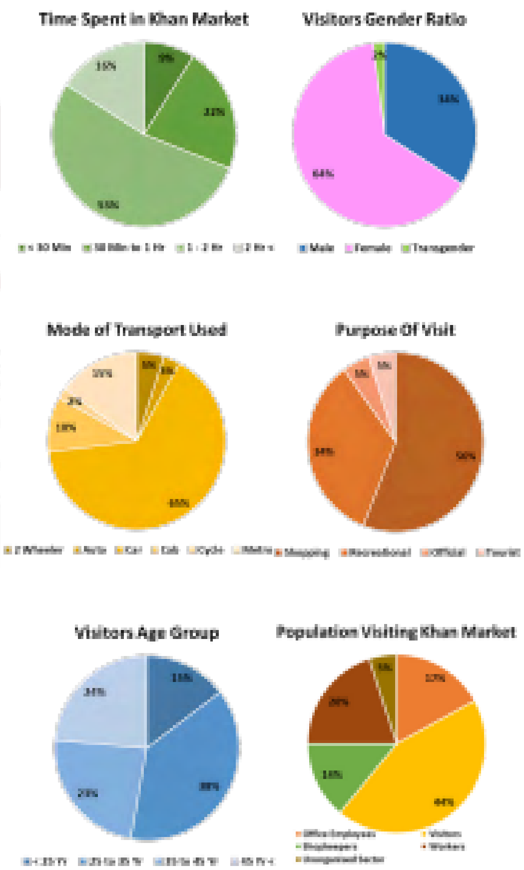

Figure 8. Demographics ~Author

Broader Implications for Urban Design

Khan Market is emblematic of many urban nodes in Indian cities that face the pressure of commercialization while carrying deep cultural resonance. Lessons from this case study can inform interventions in other traditional markets, civic spaces, and institutional campuses. Human-Centered Design, when applied through the lens of empathy and participatory planning, has the capacity to balance economic vitality with social well-being. It encourages designers to consider diverse user needs, integrate micro-interventions that scale up over time, and create spaces that are welcoming, adaptable, and resilient.

Through a Human-Centered Design approach—grounded in empathy, participation, and contextual awareness—urban design can integrate the five core principles: (Refer to Figure 9)

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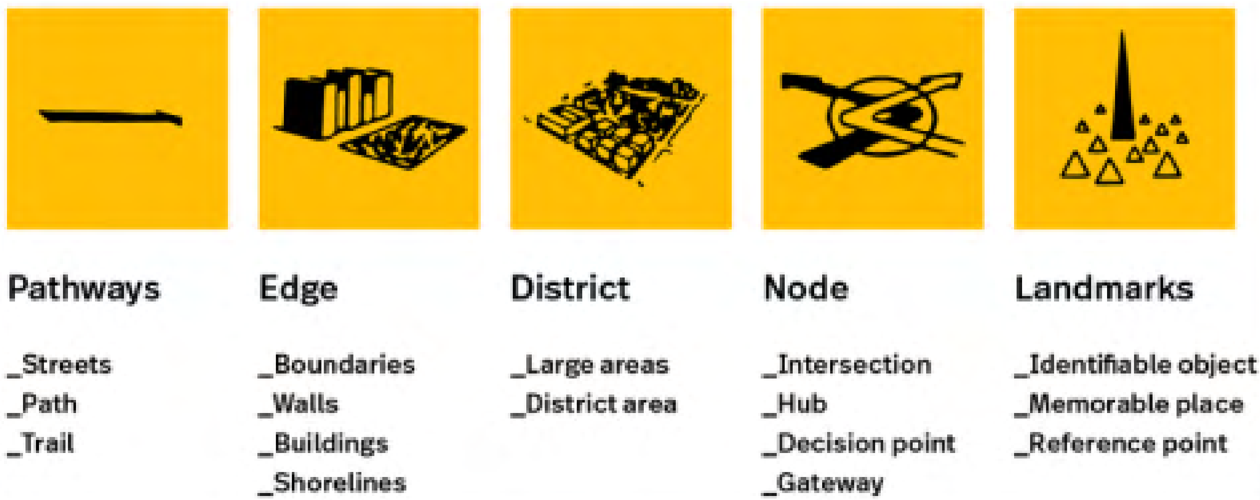

Figure 9. Kevin Lynch & his elements ~ UNICITI

Conclusion

Khan Market exemplifies the evolving relationship between place, memory, and people. Despite the challenges posed by commercialization and spatial congestion, it retains potential to transform into a model of inclusive and culturally grounded urban design. Through Human-Centered Design, the space can become more accessible, engaging, and emotionally resonant. This paper argues that thoughtful, context-aware interventions rooted in empathy can rejuvenate such spaces, reaffirming architecture's role as a facilitator of human experience, dignity, and collective identity.

Future Scope : Opportunities for Practice and Integration of HCD

Opportunities for Practice and Integration of HCD:

Human-Centered Design offers immense potential for transforming urban spaces through participatory and empathetic processes. In practice, this can include co-design workshops with local users, integrating real-time digital feedback tools, and conducting site-specific adaptive reuse. Comparative insights from similar markets—such as Connaught Place in Delhi or Colaba Causeway in Mumbai—can guide scalable adaptations.

Embedding HCD principles in everyday urban planning, from policy-level frameworks to micro-interventions, can strengthen community engagement, cultural continuity, and emotional connectivity in dense city environments. The approach is not just a tool for future research, but a viable method to be actively practiced in current and upcoming urban development projects.

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From Mandala to Masterplan:
Applying Vastu's Spatial Philosophy in Climate-Responsive Urban Design

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Abstract:

In today's world, the major issue that lies ahead of us is the rapid industrialization and urbanization accompanied by the ever-increasing climate crisis. This has led to the need to rethink urban planning models for the cities. In this research we will be revisiting the age-old Indian concept of spatial planning called Vastu-Purusha Mandala. This valuable tool has helped to shape the climate-responsive urban design concept in the past. This study will explore the deeper environmental intelligence of Vastu that can align human habitation with the forces of nature that will in turn promote balance, sustainability, and well-being rather than just solely viewing Vastu through a traditional or ritualistic lens.

The initial part of the paper will contain the historical and theoretical context of Vastu Shastra in India along with a discussion of its core elements, including but not limited to orientation, elemental balance (earth, water, fire, air, space), mandala grids, etc. The research paper will focus on drawing parallels between the age-old Vastu Shastra principles and the modern urban design interventions to elaborate on how the ancient wisdom knowingly/unknowingly anticipated many contemporary sustainability goals, such as solar access, maximized natural ventilation, and integration of green and blue infrastructure.

The paper will analyze the practical ways in which Vastu-informed planning has influenced large-scale urban planning environments through the case studies of historic settlements such as Jaipur and Fatehpur Sikri, along with the study of modern reinterpretation like Amravati. It will further discuss climate-responsive strategies like street orientation for passive cooling, public squares for heat mitigation, and zoning based on functional synergy and how these strategies can be inspired by the Vastu Purush Mandala's spatial planning concepts.

The paper will also address the difficulties in integrating vastu in contemporary urban setups. It will discuss how, instead of rigidly applying outdated Vastu principles, people need to apply a flexible approach that can smoothly balance timeless spatial wisdom with modern technology, industrial innovations, site context, demography, and practical planning techniques requirements. The paper will conclude by proposing a brand new hybrid model that will incorporate new innovative design tools and site contextual data with the Vastu Shastra principles, which will help to generate a more dynamic urban development.

Ultimately the paper will conclude with the thought that the Vastu is not only a traditional spatial philosophy but also an adaptable framework that can offer cities a new way towards more sustainable, resilient, socio-culturally vibrant, and healthy urban settings. By moving "From Mandala to Masterplan," we as architects and urban designers can bridge the gap between timeless "Vastu Shastra" principles and "21st-century rapid urbanization" and create a "new advanced settlement" that is not only highly sustainable but also climatically, culturally, and spiritually aware.

***Keywords**: Urban Planning, Vastu-Purusha Mandala, Sustainability, Masterplan, Vastu Shastra, Urbanization.*

ISBN 978-93-342-4408-3

Introduction

Urbanization and the Imperative for New Paradigms

Urbanization in the 21st century stands as an important force, which makes great promises, but also presents significant obstacles. The city now progresses in innovation, economics and cultural vibrancy. Nevertheless, they face increasing responsibility for planetary challenges - from climate change and lack of resources to social inequalities. While occupying just 2% of the earth's land, urgency for more than 70% carbon emissions of urban areas, ecologically durable, culturally arbitrary and socially inclusive urban strategies is more pressing than ever.

Rethinking Urban Planning: Where Modernity Falls Short

The current urban planning spots the technical skills, rapid infrastructure, and economic production. However, these objectives result in often disgruntled, environmentally incompatible, and culturally disconnected urban places. Re -discovering traditional knowledge systems that reduce harmony between people and the natural world are essential for further -thinking planners and communities.

The Legacy of Vastu Shastra: Ancient Intelligence for Today's Urbanism

Unfolding the Vastu-Purusha Mandala: Originated by the deep architectural legacy of India, the Vastu Shastra stands as a compilation of spatial intelligence. Its foundation lies in Vastu-Purusha Mandla: a sacred planning grid that encounters principles for balance, orientation, and functionality. Decoding Vistu beyond customary rituals reveals a science contained in close observation, holy geometry, and overall balance. This discussion reflects Vastu's principles again, which discovers their integration with digital devices such as GIS, BIM, and parametric design, and creates a new synthesis of ancient and modern urban strategies.

Vastu Shastra: Historical Roots and Spatial Philosophy

Scriptural Foundations and Core Beliefs: "Vastu" (Housing) and "Shastra" (Science) create a cruise of this spatial theory, which are deeply inscribed in Vedic texts such as Manasara and Samrangana Sutradhara. These ancient sources write a functioning for site selection, orientation, ratio and symbolic design. Cosmic Order (RTA) decides that all manufactured environments echo with universal energy, harmonize in solar, air and water flow, and unite materials and spiritual places.

Image 1: Vastu Purush Mandal (Source: Harmonizing Urban Spaces: Sustainable Design Principles from Vastu)

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Noteworthy Examples:

- The mayamata demonstrate spatial hierarchy along with showcasing climatic sensitivity with psychological comfort..
- King bhoj's Samrangana Sutradhara showcases green architectural concepts through concepts of water management and climate adaptive courtyards.

What is Urban Design and why is it the need of the hour?

Jonathan Barnett once said that Urban design means "designing cities without designing buildings". Urban design is basically an intertwined art of shaping cities, towns and public places to create a more functional, everlasting and eye pleasing environment.

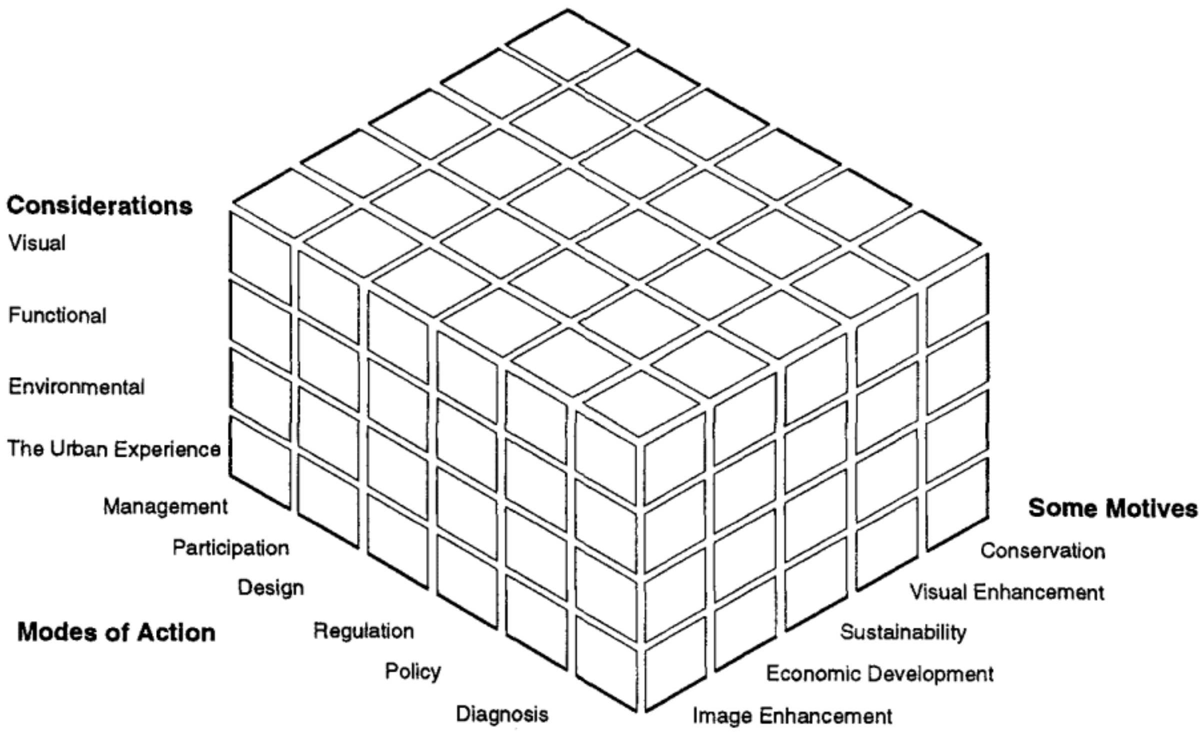

Image 2: The interaction of urban design considerations, motives and modes of actions (Source: Alan Rowley)

It mixes architecture, landscape design and urban planning to orchestrate how buildings, roads and open spaces interact to support human activity and welfare.

In today's rapid urbanization world, urban design is more important than ever. With more than half of the global population living in cities, the quality of urban life rests on how well these places are designed. A well designed urban space can:

- **More walkable and connected space:** People can walk around comfortably and everything is in walkable distance so that vehicular use is limited.
- **Promoting Social Interaction:** Spaces should be provided for friendly meet and greet amongst the citizens.
- **Improvement in overall health (mental as well as physical)**

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- **More economic growth:** Market, leisure, social spaces that will attract people as well as businesses.

Image 3 : Urban Design Concepts (https://design.udlvirtual.edu.pe/en/what-is-urban-planning-in-architecture.html)

In addition, urban design plays an important role in the climate flexibility, the justified access to the infrastructure and the psychological welfare of the citizens. As the increasing challenges in cities are faced-from dagger to environmental decline-urban design offers an active, human-focused approach to shaping the lustable futures.

The Vastu-Purusha Mandala as Urban Blueprint

A grid of 64, 81, or 256 squares, Mandla maps divine and natural powers on physical ground. Brahmathan (center) symbolizes balance. Four cardinal axes are defined to the layout combined with sunlight and air, while the diagonals represent fundamental forces such as fire and air.

For example, The temple city of India, Madurai, the city plan mirrors the Mandala. Here the routes are concentric, radiating from the shrine situated in the center. This pattern weaves together the spiritual and the civil life.

- **Urban Mandala Layout of Madurai:** Meenakshi temple lies in the center of the city, the city further radiated into concentric square following the alignment of the shrine. The city resembles the Mandala named “Sri Yatra Mandala”, this mandala is typically used to represent the universe, spiritually and architecturally. The city of Madurai artistically amalgamates the ancient mandala into a city plan.
- **Cardinal Alignment of the streets:** The streets and buildings are aligned along the four cardinal directions, namely, east, west, north and south. The structures facing EAST help in maximizing the impact of morning sun, wish resembles eternal light and energy. The streets are planned in such a way that it maximizes the natural airflow and ventilation.

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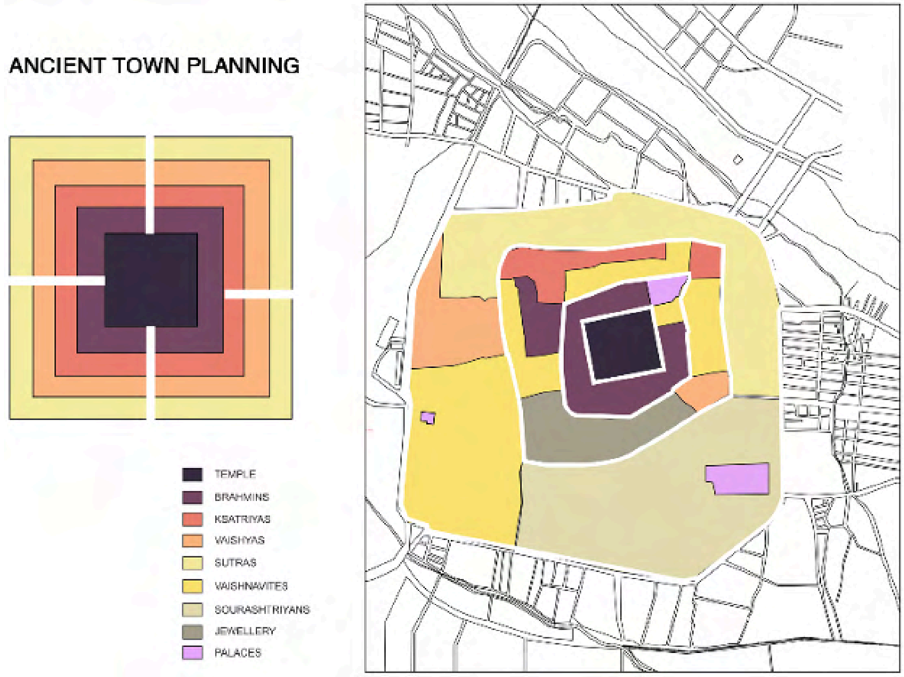

Image 4 : Zoning of Madurai City based on Caste hierarchy and comparison of ancient planning and Madurai city plan

- **The FIVE elements: PANCHA-MAHABHUTAS**, the architecture of city aligns with all the five elements of nature namely:

S.No	ELEMENT	VASTU RESEMBLANCE	REPRESENTATION
1.	EARTH	PRITHVI	Foundation and soil
2.	WATER	APAS	waterbodies, tanks, stepwells.
3.	FIRE	AGNI	kitchens, bonfires, ritual fires.
4.	AIR	VAYU	windows, doors, ventilation, breezeways
5.	SPACE	AKASHA	courtyards and highrise towers.

Table 1: PANCHA-MAHABHUTAS (Source: Author)

- **Geometrical shapes:** The city uses mathematically precise shapes having fixed and proportional dimensions and shapes, like circles, triangles and squares. These shapes are believed to radiate cosmic powers which tends to generate spiritual resonance which helps people feel divinity just by simply moving through spaces.

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- **"Pranic" flow:** Pran in sanskrit means life. Pranic flow means the energy of the flow of life. The arrangement of built and unbuilt is in such a way that it stimulates a smooth flow. The open spaces like courtyards, corridors and thresholds in houses and temples allows energy like air and light to flow within. This energy nourishes the spaces and body both physically as well as spiritually.

Vastu Shastra as a Model for Sustainable Urbanism

If one drives deeper into the true meaning of vastu Shastra, it can be a powerful representation of a indigenous sustainable urbanism. It can contribute to be a powerful modern sustainable planning by:

1. **Providing a holistic approach in stiching Space and Ecology:** Vastu Shastra believes that built, unbuilt and human beings are all interconnected in this universe. It emphasises on creating a balance between all the pancha-bhutas to have a more sustainable approach to the world. It says that inclusion of Vastu Shastra should be the integral part of the planning and not just a supplement.
2. **Emphasis on passive energy use and orientation:** Vastu shastra deliberately emphasizes on placing the window and open areas towards East and North to maximize natural light and ventilation. This idea consequently indicated the need to reduce the reliance on artificial methods of heating and cooling. This involves a deeper study of the local climatic conditions.
3. **Softscape integration**: According to vastu, water bodies need to be placed in the Northeast. Northeast direction traditionally indicated abundance and purity. In urban planning, northeast direction can be embedded with blue green infrastructure including rainwater harvesting, stormwater management, hydrological resilience etc.
4. **Psychological Impact:** The vastu planning which revolves around space, light, connectivity and symmetry at the end contributes to physical as well as mental well being of the user. After the pandemic, designers emphasize on more urban wellbeing and wellness centered design.
5. **Community Coherence and Harmony**: Traditionally, Vastu shastra emphasises on zoning the area according to its usage and energy flow like worshiping, sleeping, cooking, planting etc. Upon upscaling the view, one can translate it into functional zoning at an urban level. The zoning has to be morally and spiritually correct, instead of being just profit driven.
6. **More inclusivity, equity and innovation:** Traditionally housing were designed for individual dwellings and not for compact, high density urban buildings which roar vertically. This type of rigid, mechanical planning conflicts with many vastu placement principles, resulting in disturbance in chakras. Even though vastu can be used as a guiding framework but one should not use it alone, instead it should be blended with scientifically proven sustainable metrics like LEED, GRIHA and adhere to the local context.

In conclusion, one can say that Vastu Shastra can work as a model for "A CULTURALLY ROOTED REGENERATIVE CITIES". It will not only provide a philosophical framework for a self sustainable city but also spiritually and culturally inclined and "WOK" city. Surprisingly, this "pre-modern" wisdom system somewhat aligns and resonates with the philosophies of today's "postmodern" urban trends like steady and slow living, ever circulating economy and a vibrant ecological balance.

Lessons from Practice: Comparative Urban Case Studies

I. CASE I: JAIPUR - GRID MANDALA

Jaipur was founded by maharaja Sawai Jai Singh II in the year 1727. It is considered to be one of the earliest planned cities in India which is strictly based on ancient vastu shastra principles.

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Vastu consideration: city's planning mainly indicates 9 X 9 mandala grid which explicitly represents the cosmic order also known as "Pitha mandala". Each square represents a sector which is also known as "chowkri" in the local language. Each grid is dedicated for a specific function like residential, commercial, mixed use, religious, royal and administrative sectors. This concept reflects the idea of creating a balance and a specific purpose in each grid according to the directions indicated in the Vastu purush mandala.

Urban Design introspect: To enhance ventilation, pedestrian flow and thermal comforts, the roads are made wide and straight in alignment to the cardinal directions. The Chaupars (covered arcades) not only offers shade but also enhances the trade and commerce of the area by providing human comfort into the economic activity zone. Planning of Jaipur is a perfect example of the fact that a well executed cosmological planning can not only provide a highly functional but a liveable urban form.

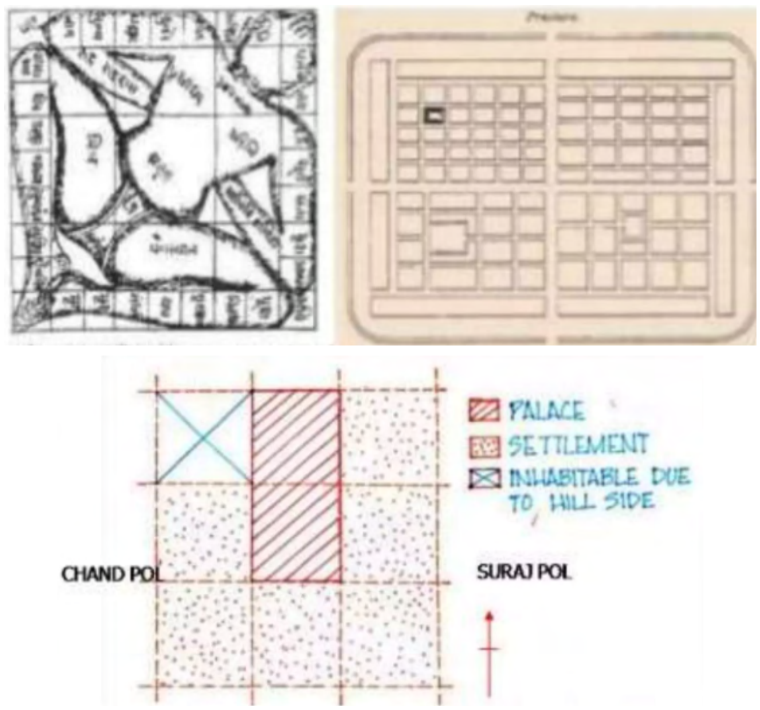

Image 5 : Planning of Jaipur (Source: Slideshare)

II. CASE II: FATEHPUR SIKRI - A PERFECT SYNC

Fatehpur Sikri is a well known UNESCO heritage site which is known for its unique architectural blend of Persian, Indian and Islamic style. It was built by Emperor Akbar in the late 16th century near Agra.

Vastu consideration: One cannot say that Fatehpur sikri has completely adapted all the principles of Vastu Shastra but it has certainly adopted few of them like, alignment of roads and streets along the cardinal axis, the zones are placed in hierarchy in the city and placements of various sectors are according to directional orientation. The central axis of the royal complex consists of Diwan-i-khas, Panch Mahal and Jama Masjid in complete alignment for complete visual and symbolic values. This indicates vastu's principle of central axis alignment and symmetrical planning.

Urban Design introspect: Fatehpur Sikri's plan roughly shows some influence of the traditional vastu shastra balanced by aesthetic yet functional requirements of the Mughal architecture. The

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structures are planned in such a way that the courtyards, jalis and the internal water bodies have a passive cooling effect in the internal atmosphere showcasing a brilliant example of a strategic climate control. It is a perfect example to show that symbolic and spiritual design can also be culturally and climatically responsive.

Image 6 : Courtyards and Open spaces of Fatehpur Sikri (Source: Archnet)

III. CASE III: AMRAVATI - A SMART CITY

Amravati was built on the grounds that it will be a blend of smart city technology and the traditional vastu planning concept. It was proposed to be the next capital of Andhra Pradesh.

Vastu consideration: The masterplan is oriented on the cardinal axis and has its elements zoned according to the vastu purusha mandala, for instance, water bodies are typically placed in the northeast direction, administration in the southwest and open space for gathering in the center. In the masterplan central space is dedicated to the governing body, this is a typical concept in Vastu Shastra.

Urban Design introspect: Since the zoning is based on the top-down manner, for instance, central spaces for higher authorities and further we go, it is dedicated to lower castes, it has led to limitation in the community engagement, people in the outermost layer faces delayed services and constant displacement issues. This in turn has affected the core principle of Vastu which states that there should be harmony between the people and spaces apart from the built structures. This planning has failed in terms of engaging local communities in the area, resulting in the least culturally resonant environment.

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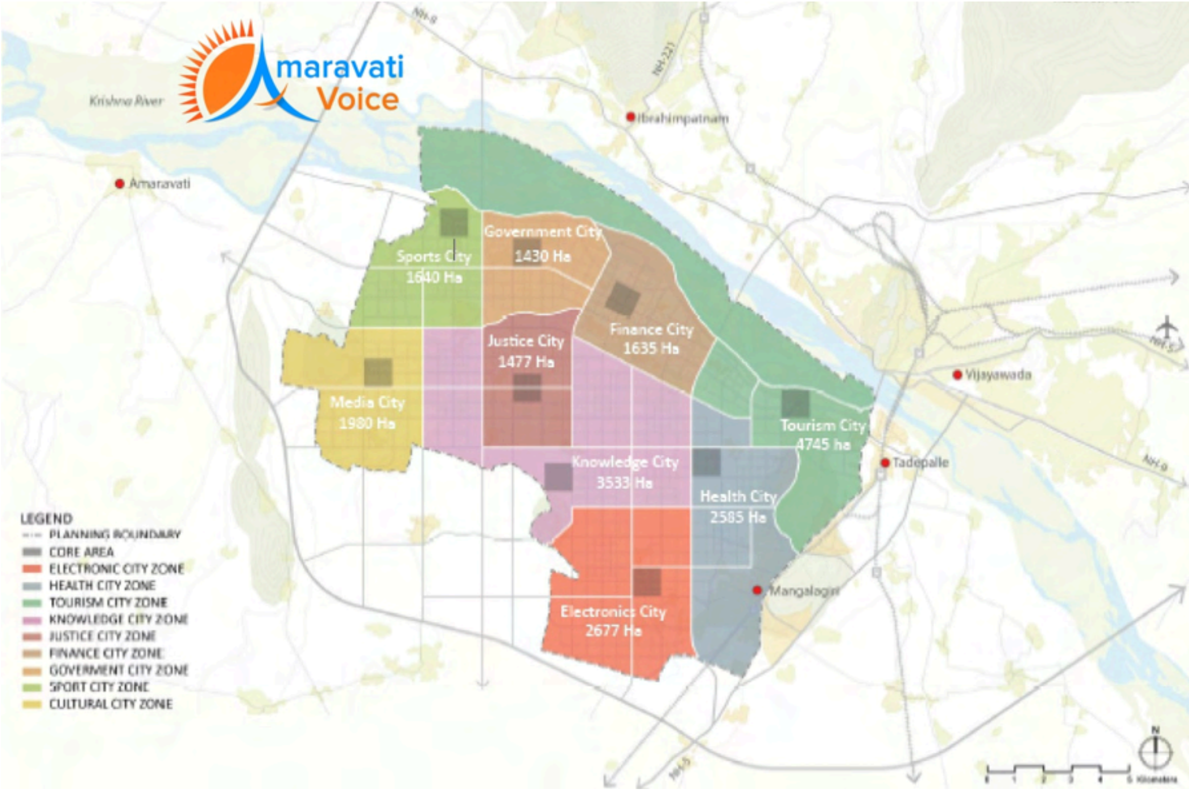

Image 7 : Amaravati master plan having administration spaces in the center followed by commercial and economical spaces and finally residential for common people (Source: Amaravati Voice)

SUMMARY- COMPARATIVE ANALYSIS

Parameter	Jaipur – Grid Mandala	Fatehpur Sikri – Perfect Sync	Amaravati – A Smart City
Time of Establishment	1727, by Maharaja Sawai Jai Singh II	Late 16th century, by Emperor Akbar	Proposed in 21st century
Vastu Application	Strong and direct—9x9 *Pitha Mandala*, functional grids reflect directional principles	Selective—alignment along cardinal axes, hierarchical zoning echoes some Vastu tenets	Claimed—orientation on cardinal directions and zoning follow *Vastu Purusha Mandala*
Spatial Organization	Sector-wise (*Chowkris*) with defined functions: residential, royal, commercial, etc.	Central royal complex with axial and symmetrical planning	Top-down zoning with administrative center; outward hierarchy for socio-economic functions
Urban Morphology	Gridiron network aligned with cardinal directions	Organic layering with enclosed courtyards, axial hierarchy	Concentric organization mimicking mandala structure but with modern overlays

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Climate Responsiveness	Wide roads, ventilation channels, and *chaupars* enhance thermal comfort	Jalis, internal water bodies, shaded courtyards offer passive cooling	Smart tech potential exists, but implementation lacks social and climatic resilience
Cultural Integration	Deeply embedded—reflects Rajput and Hindu cosmological values	Blended—Islamic, Persian, and Indian styles interwoven with limited Vastu principles	Aspirational—symbolic spatial conformity with limited community contextualization
Socio-Spatial Equity	Functionally diverse yet spatially inclusive grid	Hierarchical but integrated ensemble of royal and civic spaces	Inequitable—core areas privileged; outer zones underserved; weak local participation
Symbolism & Spirituality	Embedded through mandala logic and Brahmasthan metaphysics	Central axial alignment expresses spiritual and visual unity	Symbolic gestures exist (central plaza) but lack affective connection with residents
Key Urban Concerns	Managing heritage amidst modern urban growth	Conservation pressures and adapting to modern use	Disconnection from local culture, weak engagement, and social displacement
Suggestions for Improvement	Integrate heritage with smart mobility, enhance adaptive reuse strategies	Utilize the site as a learning model for syncretic and resilient planning	Reframe Vastu use beyond symbolic zoning; employ participatory design and context-driven smart solutions

Table 2: Comparative Analysis (Source: Author)

Contemporary Applications: Translation of Vastu into modern urbanism:

We can achieve a highly functional, harmonious and visually pleasing arenas and space if we try to translate Vastu Shastra into a modern urban setting.. These ancient traditional principles can easily amalgamate into our contemporary architectural world to provide astonishing results.

Key Aspects:

- **Road layouts and building orientations:** The structures have to be aligned into cardinal directions to manifest positive vibrations. Site and building should also be aligned in the cardinal directions to achieve this.
- **Material Selection:** Sustainable and natural materials like bamboo,wood, glasses, fabrics etc should be incorporated in the design for Vastu compliance.
- **Zoning:** The rooms should be placed strategically so that maximum energies can flow through doors and windows even in compact spaces.

Modern Applications: Most of the Vastu principles can be applied to the high-rise buildings and apartments creatively through mirrors to reflect light and create an illusion of bigger space. Vastu can be seamlessly integrated into villas and plotted housing through naturally occurring sustainable materials and

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spacious, well ventilated layout. Smart homes concept can also be applied to the new as well as old homes to control light and climate as per the vastu requirements.

Benefits: By integrating vastu into our modern life and space planning, one can promote a comprehensive well-being of the individual. It is traditionally said that adhering to the vastu principles, one can attract good fortune and financial prosperity. Vastu also promotions sustainability by promoting eco-friendly practices and local material.

Challenges in Integrating Vastu with Contemporary Urban Forms

The challenges which are faced while integrating vastu shastra in the contemporary urban form:

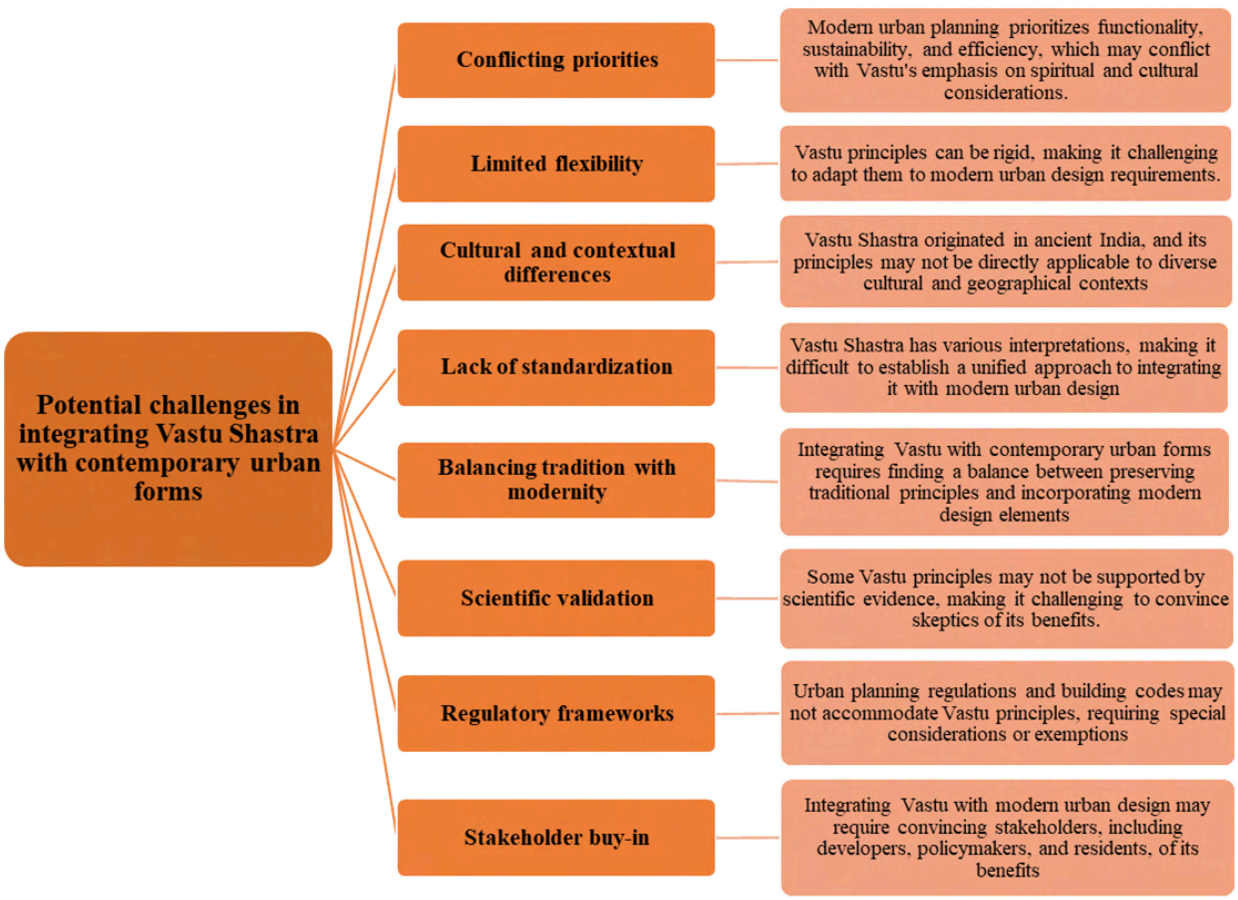

Image 8 : Challenges in integrating Vastu in Urban Design (Source: Author)

CONCLUSION

The Path Ahead: Toward a Hybrid Urban Planning Model

The Combination of modern urban planning with traditional Vastu Shastra can lead to well-balanced, sustainable, and culturally rooted urban development. Here are some key points explaining how the two can complement and help each other:

1. **Functionality with Energy Balance**
    a. Urban Planning focuses more on efficient land use, infrastructure, and accessibility Whereas Vastu Shastra on balancing the five elements (earth, water, fire, air, space) and directional energies for balanced life.

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b. Together, they can ensure that buildings are functionally efficient and energetically harmonious which is a great blend to have a healthy environment.

2. Orientation and Layout

a. Vastu Shastra focuses more on the orientation of buildings (e.g., entrance from East or North) whereas Urban planners can incorporate zoning policies in the designs that respect orientation preferences where feasible.

b. To blend both, Streets and plots can be aligned with cardinal directions, benefiting both planning and Vastu principles.

3. Natural Light and Ventilation

a. Vastu Shastra suggests open spaces in the North and East for better sunlight and air whereas This aligns with green building norms in modern planning that advocate for natural lighting and ventilation, reducing energy use. As it will incorporate more diffused light or low glare light hence reducing the heating and less burden on appliances.

4. Sustainable Resource Management

a. Vastu Shastra advice to keep water sources in the Northeast, which is helpful in rainwater harvesting and water-sensitive urban design. Integrating these can enhance ecological planning, drainage, and reduce heat island effects.

5. Psychological and Cultural Acceptance

a. Designs based on Vastu Shastra can offer psychological comfort and cultural relevance to residents.

b. Urban projects that respect cultural beliefs may face less resistance from communities, making implementation smoother.

6. Public and Private Space Balance

a. Vastu Shastra emphasizes more on open courtyards and community interaction areas specially in the centre (Brahmasthan) and In Urban planning can blend this with modern concepts of shared green spaces, parks, and pedestrian zones, enhancing social cohesion.

7. Disaster Resilience and Climate Adaptation

a. Vastu's directional principles often avoid construction in flood-prone or high-heat zones (e.g., heavy structures in the Southwest) and these align with modern hazard mapping and climate-responsive design in urban planning. For example, Rajasthan or certain tropical zones constructing thick-walled or heavy structures in the Southwest can trap excessive heat.

8. Architectural Form and Building Height

a. Traditional Vastu recommends stepped or tiered structures with central open space (Brahmasthan) similarly Urban design can adapt these into cluster housing, central courtyards, or atrium-style buildings, enhancing airflow and aesthetics.

9. Integrating Smart City Features with Traditional Wisdom

a. Smart urban planning includes digital infrastructure, mobility, and sustainability whereas Vastu can complement this by guiding placement of power sources, communication hubs, and minimizing negative energy interference.

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10. Heritage Conservation

a. Vastu integrated designs can help preserve traditional architectural identity and Urban planners can integrate this with heritage zones, making cities look modern but still deeply rooted in tradition and culture.

Vastu Shastra is one of the key aspects that helps us in building cities which are in harmony with the environment and the surroundings around us. Through its principles, it can help us to focus on balance, continuity and unity which can adhere perfectly to our goal of creating a highly efficient, sustainable and livable environment. Through this amalgamation of an ancient knowledge of vastu Shastra and the modern innovative urban design, one can create cities that are not just simply smart but also vibrant, livable and glorious.

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ISBN 978-93-342-4408-3

BRIDGING TRADITION AND CONTEMPORARY MODERNITY IN URBAN CONTEXT: CHAWRI BAZAR OLD DELHI.

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Abstract

The research examines how architecture responds to the urban context of Chawri Bazar and its precincts, highlighting the contrast between traditional integration and contemporary design.

Chawri Bazar, an iconic part of Old Delhi, is known for its heritage architecture, vibrant street life, intricate network of narrow lanes, and rich cultural heritage. The traditional buildings in this area feature ornate facades, intricately carved jali screens, projecting balconies (Jharokhas), and shaded courtyards. These elements reflect a profound understanding of climate responsiveness and cultural symbolism, allowing these structures to harmoniously blend with the urban fabric and enhance the cultural identity.

However, with rapid modernization, contemporary structures are beginning to stand out, introducing modern materials, typologies, and scales that challenge the coherence of the existing built environment.

By critically assessing these architectural transitions, the research reveals the tensions between preserving cultural continuity and accommodating urban change. It underscores the importance of contextual design approaches that honour historical narratives while embracing innovation. The research ultimately proposes strategic design guidelines for future architectural interventions in heritage-rich urban zones, aiming to balance heritage conservation with urban adaptability, thus enhancing liveability and resilience in rapidly transforming cityscapes.

Keywords: *Heritage conservation, Contemporary Architecture, Urban growth, spatial coherence, cultural identity, Jali screens, ornate facades.*

INTRODUCTION

Chawri Bazar is located in the heart of Old Delhi, India's rich architectural heritage. Nestles near landmarks like Jama masjid, Lal mandir, Red fort (Lal Qila), Chandni Chowk market, Ghalib ki haveli and many more, presents a unique case study for understanding how architecture responds to its urban context, especially in settings where historically significant and modern demands coexist with contemporary demands.

Traditional integration is seen in buildings reflecting local culture, material, and craftsmanship, blending into the historic environment. The havelis, with their courtyards, jharokhas (overhanging enclosed balconies), and ornate facades, reflect a harmonious relationship with the climate, social structure, and cultural practices in time. Contemporary structures often bring new materials, forms, & functions into the space which usually prioritize modern aesthetics.

The focus on individual building aesthetics can often lead to a disjointed streetscape, detracting from the sense of unity and cohesiveness that characterizes traditional urban forms. By exploring the visual and spatial relationship between old & new this study will help understand how architecture can engage with historic contexts in a way that respects and enhances their unique character.

URBAN PLANNING

The city was planned as per the Hindu architectural principles outlined in Shilpa Shastra. (Liddle,S. 2018) These guidelines helped shape the orientation and layout of buildings and public spaces.

Chawri Bazar is a road that connects Jama Masjid at one end and Hauz Qazi at the other. A metro station named Chawri Bazar is located at Hauz Qazi.

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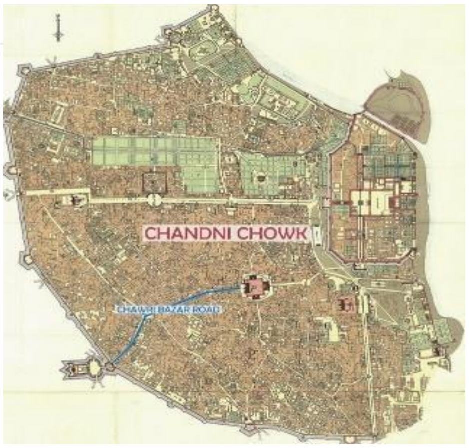
Figure Historic streetscape of Chawri Bazar: Revealing the dense urban fabric, organic street layout, (Source: Author)

Nai Sarak, which is well-known for books and women's garments, intersects Chawri Bazar at Badshah Bulla. Additionally, Ballimaran provides another route that links Chawri Bazar to Chandni Chowk.



The narrow streets of Chawri Bazar are designed mainly for pedestrian traffic, and the compact layout contributes to the area's unique, vibrant atmosphere and urban density. Traditional havelis with internal courtyard are common in the area, serving both as residential and commercial hubs. The ground floors are frequently occupied by retail shops, while the upper levels serve as residential and storage space. (Rohatgi, A. 2024).

This urban arrangement creates a dynamic commercial environment, filled with numerous small shops offering a wide range of products, from metal and brass items to wedding supplies and stationery.

While the compact nature of the area enhances community interaction, it also poses challenges in incorporating modern amenities and managing traffic flow.

Chawri Bazar, situated within lively neighbourhoods and easily accessible via the Chawri Bazar metro station, remains a significant cultural and commercial hub within the intricate urban fabric of Old Delhi. (The Indian Express, 2023)

BUILT HERITAGE & LIVING TRADITION

The walled city, formerly known as Shahjahanabad, showcases architectural marvels that reflect Mughal influence. These monuments with intricate designs, domes and minarets, along with havelis in the bustling lanes of Old Delhi, represent the grand Mughal architectural style mixed with art styles from other parts of India.

Among these vibrant historical sites, Chawri Bazaar stands out. The name "Chawri," referring to gatherings, the bazaar served as a meeting point for traders and buyers in the Mughal era.

Initially, it was a market specializing in metal goods which gradually evolved into a centre for wedding cards, stationery, and paper products. The bustling marketplace reflects the changing needs of Delhi's

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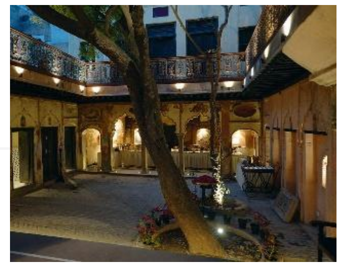
residents, blending historic charm with modern commerce. Today, Chawri Bazaar continues as a vibrant commercial hub deeply rooted in history.

The traditional havelis feature exquisite carvings, inviting open courtyards, and striking overhanging balconies that highlight both Mughal artistry and climate-responsive design principles. Constructed from local materials such as Lahori bricks and lime mortar, these structures effectively combine functionality with aesthetic appeal, creating a vibrant sense of community and cultural continuity.

Beyond its impressive built heritage, Chawri Bazar thrives as a living repository of traditions. Home to many diverse communities from generations, Chawri Bazar is a rich tapestry of living heritage. From artisanal crafts to culinary delights and religious practices, the area's intangible heritage enhances its cultural identity.





This dynamic fusion of architectural and living traditions not only celebrates its past but also underscores the pressing challenges of preserving heritage in the face of urban development.

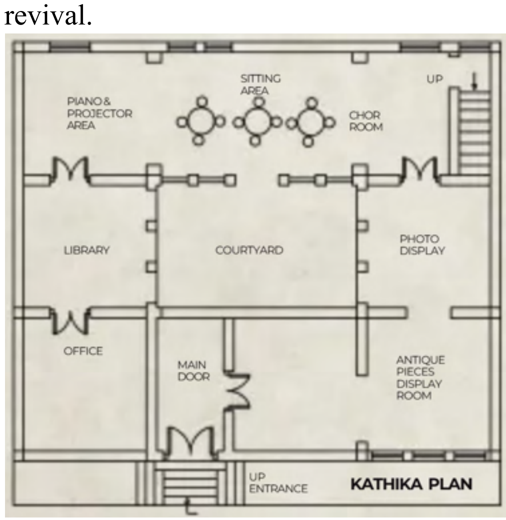
RELEVANCE OF CHOSEN CASE STUDIES

To evaluate how architecture responds to the complex urban environment of Chawri Bazar, the selected case studies showcase different approaches to the relationship between architectural expression and urban heritage. Traditional projects like Dharampura Haveli and Kathika Cultural Centre demonstrate how adaptive reuse preserves heritage while serving modern needs. In contrast, the Chawri Bazar Metro Station and Omaxe Mall represent contemporary architecture focused on efficiency and commerce, often clashing with the area's historic character and spatial context.

KATHIKA CULTURAL CENTER

A cultural space is converted - heritage haveli

The Kathika Cultural Centre is a museum and cultural centre in the historic neighbourhood of Kucha Pati Ram in Chawri Bazar, Old Delhi. The museum is housed in 19th - century haveli which offer exclusive spaces for performing art, workshop, screenings, culinary experiences, photography and baithaks, all related to heritage and cultural revival.



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This cultural space exemplifies how traditional architecture can be adapted for contemporary use while preserving its historical integrity. The traditional exteriors with contemporary interiors, the centre demonstrates a thoughtful approach to integrating heritage with modern functionality.

The building itself is not visible upfront from major roads, echoing the introverted typology of Mughal-era havelis, where privacy and inward orientation were primary.

This inward-focused design acts as a spatial and acoustic buffer from the chaotic street life outside, creating an atmosphere conducive to cultural reflection and engagement.

Material: The structure was constructed and later restored using a combination of materials like brick, stone, wood, Majolica tiles, cast metal grilles, and stained glass. These not only enhance the aesthetic appeal but also integrate into the urban environment.

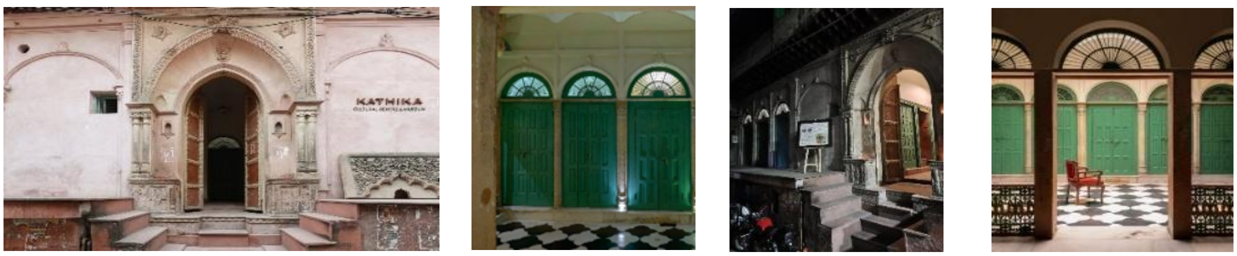

Figure 5 Kathika Cultural Centre: A restored haveli with traditional wooden doors and jharokhas, integrating seamlessly into the historic street. (Source: Author)

DHARAMPURA HAVELI

Preserving the Past, Welcoming the Present

Located within the narrow alleys of Gali Guliyan, Dharampura haveli stands as a magnificent example of the late Mughal-period domestic architecture. Originally built in 1880, this 135-year-old structure was built for a mixed-use purpose, commercial units in the lower ground level opening onto the bustling street and upper stories functioning as residences. (IJFMR Sakshi Doshi, Thoudam Sudha Devi 2023)

It was named the ‘Best Heritage Property in Delhi’ at the 12th World Annual International Travel Awards and received the 2017 UNESCO Asia-Pacific Award for Cultural Heritage Conservation.

Dharampura haveli restoration serves how architecture can be sensitively preserved and reactivated for contemporary use without compromising its historical integrity. Spearheaded by heritage activist and politician Vijay Goel. Now, the haveli functions as a heritage hotel with cultural programming, exemplifies adaptive reuse, preserving architectural memory while catering to modern hospitality needs.

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Materials: Constructed primarily from local red sandstone, the haveli reflects the region's architectural heritage. Original lakhori (kiln-baked) brick masonry enhances strength and durability. Lime mortar and wood are also integral to its construction, while traditional craftsmanship techniques in detailing elevate the structure's authenticity and aesthetic appeal.

CHAWRI BAZAR METRO STATION

Urban transit infrastructure

Chawri Bazar Metro Station is more than just a transit point on the Delhi Metro's Yellow Line. It serves as a gateway to a world that beautifully blends the old with the new. From the bustling streets of Chawri Bazar (North Delhi) to the grand architecture of Jama Masjid, this metro station is your entry point into the vibrant, historical tapestry of Old Delhi. Inaugurated in 2005, the station represents a critical infrastructural intervention that sought to address urban mobility issues in one of the most compact urban areas of Delhi.

Chawri Bazar Metro Station is part of the Yellow Line of the Delhi Metro, which connects Samaypur Badli in the north to Millennium City Centre in the south. The station is located underground, about 25 meters below the surface, making it one of the deepest stations in the network.

The integration of the Delhi Metro into the dense and historic fabric of Old Delhi demonstrated remarkable architectural and engineering precision. Above ground, there was virtually no scope for new construction without disrupting existing economic activity or demolishing heritage structures. Below ground, the subterranean landscape was equally complex an amalgam of centuries old foundations, sewer networks, undocumented utilities, and unpredictable soil conditions. Its design and execution had to operate within the framework of urban invisibility, a rare but necessary approach in cities where every square meter is saturated with memory, meaning, and function. (DMRC 2021)

Material: The construction utilizes reinforced concrete and steel for structural integrity, while the finishes include tiles and glass for a clean, modern look. Energy-efficient lighting and ventilation systems further enhance its functionality and sustainability.

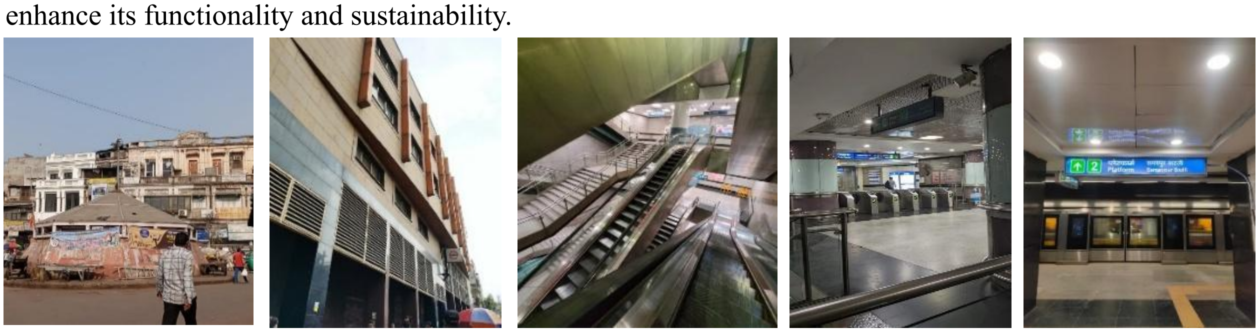

Figure 8 Chawri Bazaar Metro Station: Located in Old Delhi, connecting the bustling market area with modern transit, blending tradition and convenience. (Source: Author)

OMAXE MALL *Modern commercial complex*

Omaxe Mall stands as a significant example of modern urban architecture in an area that is deeply rooted in history and traditional architectural styles. It demonstrates how contemporary architecture can either integrate with or contrast against the urban landscape.

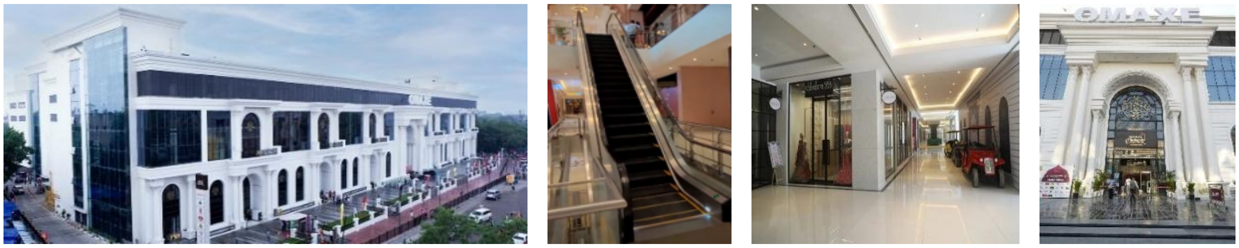

Figure 9 Omaxe Mall: A contemporary commercial landmark introducing modern retail, dining, and entertainment amenities into the historic urban fabric of Old Delhi. (Source: Author)

Unlike the intricately detailed Mughal-era havelis, colonial facades, and vernacular shop-houses that define the area's identity, Omaxe Mall embodies a contrasting architectural ideology characterized by scale, materiality, enclosure, and a sense of urban detachment. It serves as an example of how architecture can engage with or isolate itself from its surroundings.

The mall promotes vehicular access and centralized consumption, contrasting with the pedestrian-oriented, decentralized market model of Chawri Bazar. Parking facilities and service entries break the continuity of pedestrian movement, while its inward retail program reduces street-level vibrancy, often essential to Old Delhi's socio-economic life. The mall operates as an enclave, rather than a node of urban interaction.

Omaxe Mall is not only a commercial building but also a critical representation of contemporary urban aspirations that clash with heritage-driven spatial narratives.

Material: The mall employs modern materials, including concrete for structural strength, glass for transparency that allows natural light and views of the bustling market, and steel for durability and a sleek aesthetic. High-quality polished stone finishes further enhance the upscale shopping environment.

COMPARATIVE ANALYSIS: TRADITIONAL & CONTEMPORARY STYLE

Aspect	Traditional Integration	Contemporary Contrast
Street layout	Organic, narrow lanes evolved through centuries, closely knitted with bazaars and residences.	Disruptive insertion of wider roads and infrastructure such as the metro station, creating breaks in the organic pattern.
Plot configuration	Irregular and small plots, maximizing land use within dense fabric.	Larger, consolidated plots for commercial redevelopment, often ignoring historical lot lines.
Built form	Clustered courtyard-based typologies with shared walls.	Isolated built forms like malls or institutional blocks with setbacks and standalone structures.
Architectural Expression	Ornamented facades with Jaali, jharokhas, and traditional motifs.	Minimalist or glass-clad facades with steel, concrete, and aluminium finishes.
Material Palette	Locally sourced materials like red sandstone, lime plaster, wood, and stone.	Modern industrial materials such as steel, RCC, glass, and composite panels.
Scale and proportion	Human-scale development with low-rise structures (2-3 storeys).	Often out-of-scale developments exceeding traditional skyline, disrupting continuity.
Thermal Comfort	Courtyards, thick walls, narrow lanes providing shade & passive cooling.	Heavy reliance on mechanical HVAC systems due to glass facades and poor thermal mass.
Ventilation	Cross-ventilation via internal courtyards & perforated screens.	Often sealed environments with mechanical ventilation, reducing environmental responsiveness.

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Use of Green Elements	Integration of plants in courtyards and terraces.	Little to no green integration, often replaced by paved plazas or parking.
Sensory Experience	Multisensory: smell, textures, sound of bustling, layered space.	Often sanitized, controlled environments with minimal tactile or acoustic variation.
Night-time Character	Lit organically with shop lights, street vendors lively after dark.	Reliant on artificial lighting; can become desolate outside business hours.
Examples in Chawri Bazar	Renovated Havelis like Dharampura Haveli, small shops with traditional facades	Modern commercial complexes with glass facades, contemporary residential apartments

CONCLUSION

In conclusion, the balance between preserving traditional architecture and embracing modernity is key to sustainable urban development. Successful architectural interventions should respect the historical context, while innovative design can contribute positively if thoughtfully integrated, ensuring the area's rich cultural heritage is preserved alongside modernization efforts

In the comparative study of Architectural Response to Urban Context: Traditional Integration vs. Contemporary Contrast in Chawri Bazar Old Delhi, we have examined how architecture reflects and interacts with the dense, historic fabric of Chawri Bazar and its nearby zones. Through an in-depth analysis of landmarks such as the Kathika Cultural Centre, Dharampura Haveli, and the modern interventions like the Metro Station and Omaxe Mall, several key insights emerge.

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ISBN 978-93-342-4408-3

Sustainable Project Management in Architectural Practice

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Abstract

In response to escalating environmental concerns and resource depletion, integrating sustainability into architectural practice has become essential. This paper examines how Sustainable Project Management (SPM) aligns architectural projects with environmental, economic, and social sustainability goals throughout their lifecycle. It explores strategies such as sustainable material use, energy-efficient design, waste reduction, and digital tools like BIM to enhance both project efficiency and sustainability. Drawing from literature and case studies, it highlights best practices including green certifications (LEED, BREEAM, GRIHA), regulatory compliance, and stakeholder collaboration. Challenges such as cost, regulations, and interdisciplinary coordination are also discussed. The study emphasizes innovative approaches like smart technologies and resource-efficient construction, which not only reduce environmental impact but also yield long-term economic benefits. By offering practical insights into SPM, this research reinforces the vital role of project management in advancing sustainable architectural practices and shaping a more responsible built environment.

Keywords: *Sustainable Project Management, Green Architecture, BIM, LEED, Resource Efficiency.*

1. Introduction

The concept of sustainability in architecture goes beyond the traditional focus on aesthetics and functionality to consider environmental, social, and economic impacts. Sustainable architecture and urban planning practices aim to create environments that support the health and well-being of individuals, communities, and the planet. As the urgency for addressing climate change increases, SPM in architecture is vital to ensuring that buildings and urban spaces contribute positively to sustainability goals.

This research paper explores the role of Sustainable Project Management (SPM) in architectural practice, focusing on methods, strategies, and tools used to manage sustainable architectural projects.Specifically, the integration of sustainability in project management processes, key examples from India, and how effective management practices can lead to achieving sustainability goals.

2. Literature Review

2.1. Sustainable Architecture in Project Management

Sustainable architecture focuses on creating designs that are energy-efficient, minimize environmental impact, and contribute positively to the local community. SPM refers to the application of project management principles and processes to ensure that sustainability objectives are met throughout a project's lifecycle.

Sustainable project management requires the collaboration of diverse stakeholders, including architects, engineers, contractors, and clients, Also include practices like reducing energy consumption, minimizing material waste, and ensuring the efficient use of water and resources.[4]

2.2. Tools and Techniques in Sustainable Project Management

Key tools used in sustainable project management include:

Building Information Modeling (BIM): A digital tool that aids in efficient project delivery by enabling real-time collaboration and resource optimization (Gupta & Patel, 2020).[4]

Green Certifications: Systems like LEED, BREEAM, and IGBC provide structured frameworks for assessing and certifying the sustainability of buildings (Sharma & Yadav, 2019).[1]

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Circular Economy: Incorporating the principles of reuse, recycling, and waste reduction into project management.

2.3. Sustainable Project Management in the Indian Context

India's rapid urbanization has brought about an increased demand for sustainable infrastructure. According to Iyer & Kumar (2018), green building certifications such as LEED India and IGBC are becoming standard practices in Indian architectural projects.

3. Methodology

This research adopts a qualitative approach, employing case study analysis, literature review and analysis.

Case Study Analysis: This study includes Indian architectural projects that have successfully implemented sustainable project management practices, analyzing their strategies, challenges, and outcomes. Case studies include The Pearl Academy, Jaipur, Infosys Pune, and Swan Lake Eco-Campus, Ahmedabad.

Literature Review: Scholarly articles, books, and existing research papers were reviewed to gain insights into sustainable project management techniques and best practices used in the architecture industry.

4. Key Findings and Discussion

4.1. Case Studies of Sustainable Architectural Project Management

Case Study 1: Infosys Pune – Green Building Practices and Sustainable Project Management

Project Overview: Location: Pune, Maharashtra, India.

Client: Infosys Technologies Limited.

Architect: Ar. Hafeez Contractor.

Building Type: IT Campus, Office Spaces.

Sustainability Goals: The Infosys Pune campus was designed with an emphasis on environmental sustainability. The project incorporated various green building strategies aimed at reducing the carbon footprint, optimizing energy efficiency, and ensuring a positive impact on the local community.

Sustainable Features and Strategies:

Energy Efficiency:The campus uses solar panels for power generation, reducing dependency on conventional electricity.

The campus is designed to optimize natural light, minimizing artificial lighting needs.

High-efficiency HVAC systems (heating, ventilation, and air conditioning) were installed to reduce energy consumption.

Water Conservation: The project includes rainwater harvesting systems and wastewater treatment plants to recycle water for landscaping and other non-potable uses.

Water-efficient fixtures and low-flow systems have been installed in all buildings to reduce water consumption.

Materials & Waste Management: Environmentally friendly materials were chosen, including low-VOC paints and recycled materials for construction.

A robust waste management plan was implemented during construction to reduce waste and promote recycling.

Certifications: The Infosys Pune campus received the LEED Platinum certification for its commitment to sustainable design and construction practices.

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Graph 1: Energy savings at the Infosys Pune campus before and after implementing energy-efficient measures.

Project Management Approach:Integrated Project Delivery: Infosys adopted an integrated project delivery approach to ensure collaboration between architects, engineers, and contractors from the initial stages of design to project completion.

Technology Use: The use of Building Information Modeling (BIM) allowed for better coordination, reducing errors and improving efficiency during construction.

Key Takeaways: The Infosys Pune campus exemplifies how sustainable project management principles, like energy efficiency, waste management, and green certifications, can be implemented in large-scale IT infrastructure projects.

The use of BIM technology for better planning and project execution is a noteworthy example of integrating technology in architectural design for sustainability.[2]

Case Study 2: Pearl Academy Jaipur – Sustainable Design and Green Construction Practices

Project Overview:

Location: Jaipur, Rajasthan, India.

Client: Pearl Academy.

Architect: Studio Lotus.

Building Type: Academic Campus, Educational Facilities.

Sustainability Goals: Pearl Academy Jaipur aims to create a learning environment that not only promotes creativity and education but also adheres to sustainable design principles. The campus was built with a strong focus on energy-efficient design, resource optimization, and integrating the local culture.

Sustainable Features and Strategies:

Natural Ventilation and Daylighting: The buildings are designed to maximize natural ventilation and daylighting, reducing the need for artificial lighting and cooling.

The use of large windows and open courtyards helps maintain thermal comfort, reducing the need for air conditioning.

Green Materials: The construction utilized locally sourced materials, which not only reduced transportation energy but also promoted the local economy.

The use of mud blocks in construction contributed to a lower carbon footprint and enhanced the building's thermal insulation.

Water Efficiency: The campus features rainwater harvesting systems to collect and reuse water for landscaping and other non-potable uses.

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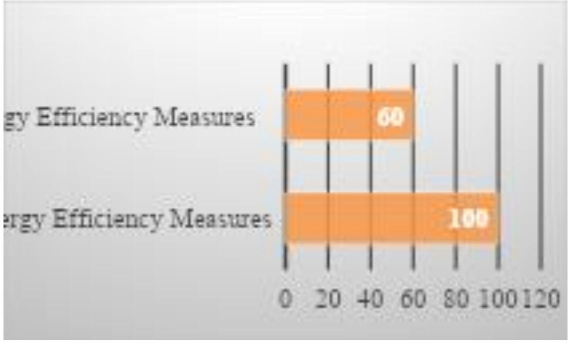
The landscaping is done with native plants that require minimal water, contributing to the reduction in overall water consumption.

Waste Reduction: A sustainable approach was adopted for waste disposal during construction, with a focus on recycling and reusing materials.



Graph 2 : Comparison of water consumption before and after rainwater harvesting systems at Pearl Academy Jaipur.

The design incorporates features such as composting for organic waste to reduce landfill contributions.

Certifications: The Pearl Academy Jaipur campus is certified with IGBC Certification, showcasing its commitment to sustainability.

Project Management Approach:

Collaborative Design and Construction: The project team worked in close collaboration with sustainability consultants to ensure that all building features aligned with the sustainability goals.

Technology Integration: The use of BIM facilitated better planning and resource management, optimizing construction processes and ensuring that sustainability goals were met without compromising on quality.

Key Takeaways:

Pearl Academy Jaipur is an excellent example of how integrating local materials, green construction practices, and energy-efficient design can create a sustainable educational environment.

The project's focus on water conservation, waste management, and sustainable materials underscores the importance of holistic project management in achieving sustainability.[1]

Case Study 3: Swan Lake Eco-Campus, Ahmedabad

Project Overview:

The Swan Lake Eco-Campus is an innovative sustainable development by the Adani Group located in Ahmedabad. This eco-campus was designed to be a model for sustainable architecture, focusing on environmental responsibility and energy efficiency. The campus includes advanced features such as green roofs, solar energy systems, and water conservation mechanisms. Additionally, smart technologies such as electric vehicle (EV) charging stations and energy-efficient building systems were integrated into the campus, aiming to minimize the overall ecological footprint of the project.

Key features of the Swan Lake Eco-Campus:

Green Roofs: These were implemented to reduce the heat island effect, improve insulation, and promote biodiversity. The green roofs also play a significant role in water management by reducing runoff.

Solar Energy Systems: The campus is equipped with solar panels to reduce reliance on non-renewable energy sources. Solar energy provides a substantial portion of the campus's electricity needs.

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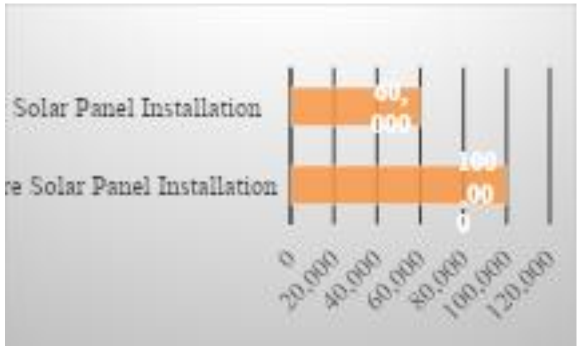
Water Conservation: The campus integrates rainwater harvesting and wastewater treatment systems to minimize water wastage and ensure sustainability.

Smart Technologies: The inclusion of electric vehicle charging stations encourages the use of electric vehicles among campus employees and visitors, reducing the carbon footprint. Additionally, energy-efficient HVAC systems and smart lighting ensure that energy consumption is minimized.



Graph 3: Comparing the energy consumption before and after the integration of solar panels

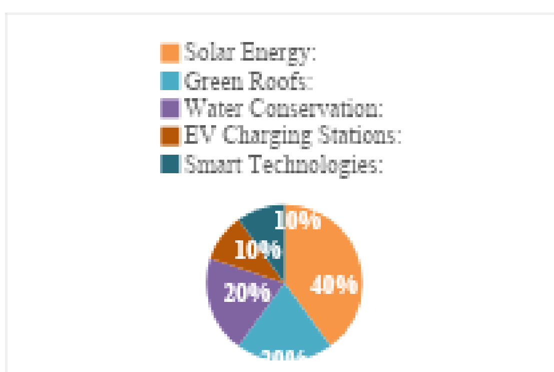
Sustainable Project Management Approach:

The project management team at Swan Lake Eco-Campus adopted a holistic approach to sustainability, ensuring that environmental, economic, and social factors were considered at each stage of the project. The approach was characterized by the following principles:

Environmental Sustainability: Every decision was made with the goal of minimizing environmental impact. Green roofs, renewable energy systems, and water management techniques were incorporated into the project's design to ensure the campus was as eco-friendly as possible.

Economic Sustainability: The project aimed for long-term cost savings, particularly in terms of energy and water consumption. The integration of solar panels and energy-efficient systems reduces operational costs. The project also aimed to attract tenants and companies with strong sustainability credentials, ensuring its financial viability over the long term.

Social Sustainability: The project focused on creating a healthy, sustainable environment for employees and visitors. This includes access to green spaces, reducing the heat island effect through the use of green roofs, and creating an energy-efficient campus that minimizes the environmental impact on the surrounding community.



Pie Chart 1: The proportion of sustainable technologies and strategies integrated into the campus.

Key Takeaways:

The Swan Lake Eco-Campus highlights several key takeaways in sustainable project management:

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Effective Collaboration: One of the main factors behind the success of the project was the collaboration between various stakeholders, including architects, engineers, and sustainability experts. This ensured that sustainability was integrated at every stage of the project and in every aspect of design and construction.

Integrated Green Technologies: The use of integrated green technologies, such as solar power and green roofs, is critical in reducing the campus's ecological footprint. The project successfully achieved energy efficiency through smart building systems, which lowered operational costs and carbon emissions.

Smart Technologies: The adoption of electric vehicle (EV) charging stations and smart energy systems was an important part of the project's sustainability efforts. These smart technologies not only support the goal of reducing carbon emissions but also promote a sustainable lifestyle for the campus's occupants.

Challenges and Solutions:

While the project was successful, it faced several challenges:

Cost Considerations: The upfront costs of implementing solar panels, green roofs, and energy-efficient systems were significant. However, these investments were justified by long-term savings in energy and water costs.

Technology Integration: Incorporating smart technologies required seamless integration (Placeholder1) between architectural design, engineering, and sustainability experts. This required advanced planning and constant communication to ensure that all technologies worked together harmoniously.

The Swan Lake Eco-Campus serves as a case study in how large-scale sustainable architecture projects can be successfully implemented when various stakeholders work collaboratively and focus on long-term sustainability goals.[3]

4.2. A. Best Practices in Sustainable Project Management in India

Adoption of Green Building Certifications:

LEED India and BREEAM are widely recognized in India, with Mumbai's CII-Sohrabji Godrej Green Business Centre becoming the first building in India to receive a LEED Platinum certification. These certifications encourage building owners to optimize energy and water use, reduce waste, and use sustainable materials.

Building Information Modeling (BIM):

Tata Consultancy Services (TCS) Mumbai adopted BIM for integrated project delivery, which significantly improved collaboration and reduced errors during the design and construction phases. This technology played a pivotal role in enhancing the sustainability of the project. [3]

B. Graphs/Charts/Flowchart for Sustainable Project Management

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Flowchart 1: The sustainable project management process for case studies, similar to the one we previously created, highlighting the key stages and strategies

4.3. Challenges and Solutions

Challenge 1: Cost Constraints

Many projects face initial cost overruns due to the implementation of green technologies and materials.

Solution: Incorporating sustainable practices from the start and leveraging government incentives for sustainable buildings can offset these costs.

Example: Infosys Pune optimized its energy consumption by using efficient HVACsystems and renewable energy sources, which led to long-term operational savings.

Challenge 2: Regulatory Barriers

In some cases, building codes and regulations do not fully support innovative sustainable design practices.

Solution: Collaboration between developers, architects, and local governments to align building regulations with sustainable design goals.

Example: Masdar City, UAE, showed how a forward-thinking regulatory framework can enable the successful implementation of sustainable projects.

5. Conclusion and Recommendations

5.1. Summary of Key Insights

Sustainable project management is a crucial aspect of modern architectural practice. It ensures that buildings are not only efficient but also contribute positively to the environment. Case studies from India, such as The Pearl Academy and Infosys Pune, demonstrate that careful planning, the adoption of green certifications, and tools like BIM are essential for achieving sustainability goals.

5.2. Practical Recommendations for Architects and Project Managers

Early Integration of Sustainability: Sustainability goals should be integrated from the inception of the project.

BIM Adoption: BIM should be leveraged to optimize resources and improve project delivery timelines.

Cross-Disciplinary Collaboration: Architects, engineers, and sustainability experts should collaborate closely to meet environmental goals.

Incentives and Green Certifications: Obtaining green certifications helps in guiding and validating sustainability efforts.

5.3. Future Research Directions

Future studies could explore how sustainable project management can be applied to smaller-scale projects and the role of government policies in fostering a greener built environment in India.

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ISBN 978-93-342-4408-3

ENHANCING PEDESTRIAN MOBILITY: ADVANCEMENTS AND DESIGN & DEVELOPMENT APPROACH IN GLOBAL OFF-STREET PEDESTRIAN INFRASTRUCTURE

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Abstract

With the explosive growth of cities and urban populations worldwide, the design of pedestrian networks has become central to contemporary urban planning. Scholars such as Jane Jacobs (*The Death and Life of Great American Cities*, 1961) and William H. Whyte (*The Social Life of Small Urban Spaces*, 1980) underscore that vibrant, walkable environments ranging from sidewalks to pocket parks form the backbone of social safety, economic vitality, and urban health. In recent years, city planners and designers worldwide have increasingly focused on how pedestrians move through cities, designing alternative networks, such as underground cities or elevated walkways that can reduce congestion and improve quality of life, although streets remain the primary means for pedestrians to navigate cities. **This paper is based on secondary data and explores innovative pedestrian networks beyond conventional roadways using case studies like the +15 Calgary, the Tokyo Underground City, and the Minneapolis Skyway System along with the design and development approach followed, implications for pedestrianisation research and the overview of the Impact on mobility in each case.**

Introduction

Beyond classic streets, innovative infrastructure like skywalks, underpasses, elevated promenades, and linear parks are emerging in cities like Calgary, Tokyo, Minneapolis, and New York City. Charles Montgomery's *Happy City* (2013) illustrates how integrating "emotional infrastructure" fosters community well-being. Other theorists like Edmund Bacon (*Design of Cities*, 1967) and James Howard Kunstler (*Home from Nowhere*, 1998) advance critiques of car-centric development in favour of human-scale, pedestrian-first design.

Global trends highlight the urgency: since 1975, urban street networks in fast-growing cities across 90% of the world's 134 largest countries have become less connected, favouring winding, inaccessible layouts. In contrast, pedestrianisation is shown to be transformative:

- In **Pontevedra, Spain**, full pedestrianisation began in 1999. Today, more than **75% of journeys are made on foot or by bicycle**, CO_2 emissions are down by **over 70%**, and road fatalities have dropped to zero since around 2011 with **66-84%** of trips now non-motorized across studies. Moreover, motorized traffic in the historic centre decreased by **92%**, around the inner ring by **77%**, and city-wide by **53%**.
- In **New York City's Times Square**, the Broadway "Bowtie" pilot (2009) and permanent plazas (2014-2016) resulted in a **11% increase in pedestrian footfall**, **40-35% reduction in pedestrian injuries**, **15-63% fewer vehicular accidents**, and a **60% drop in local air pollutants**. 74-93% of surveyed pedestrians agree the area is safer and more pleasant, and the district now generates more than **$110 billion** annually 22% above pre-pedestrianisation levels.
- Additional examples include **Oslo**, which reported achieving *zero* pedestrian and cyclist fatalities, along with a **10% rise in foot traffic** after street redesigns; and **Minneapolis**, which has systematically expanded skyways and pedestrian plazas to maintain footfall during harsh winter months.

Economically, pedestrianisation drives growth:

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- A survey across **14 Spanish cities** found retail sales rose by up to **40%** in pedestrian zones, while in **Mexico City**, commercial activity increased by **30%** and violent crime decreased by **96%**.
- During New York's COVID-19 "Open Streets" program, restaurants and bar sales rose by **19%** in pedestrian corridors compared with a **29% decline** elsewhere helping save over **100,000 jobs**.

Academic reviews in journals like *Sustainability* (2023) reinforce that pedestrianisation reduces traffic volumes, improves air quality, lowers injuries (up to **40%** less), cuts crime (**96%** reductions), and boosts property values by thousands of dollars per home.

1. Types of Pedestrian infrastructure Beyond Streets:

Pedestrian networks beyond traditional streets are alternative pathways designed to enhance mobility, improve safety, and create more walkable urban environments. These networks are particularly useful in urban areas where street-level congestion, environmental conditions, or traffic safety concerns make walking on roads less desirable. Below are various types of pedestrian networks commonly found in cities around the world:

Table 1: Types of pedestrian infrastructure with examples

Type of Pedestrian infrastructure	**Description**	**Examples**
Elevated Walkways (Skywalks & Bridges)	Elevated structures above street level that connect key buildings, transport hubs, and commercial districts.	+15 Calgary, Minneapolis Skyway System
Underground Pathways Subways/ Underground Cities	Subterranean pathways that connect buildings, transport hubs, and commercial areas.	Underground City, Tokyo
Green Spaces & Linear Parks (Repurposed Infrastructure)	Repurposing abandoned infrastructure into pedestrian-friendly parks or walkways, often featuring gardens and recreational areas.	High Line, New York
Transit-Oriented Walkways (Integrated with Public Transit)	Walkways connecting pedestrians to public transport hubs, allowing smooth transitions between transportation modes.	London Underground
Covered Walkways (Arcades, Malls, Passageways)	Sheltered pedestrian pathways, often part of buildings or shopping districts, protecting pedestrians from adverse weather conditions.	Arcades Paris, Singapore's Orchard Road

2. Review of Off-Street Pedestrian Networks in Global Cities:

This section examines some of the most successful and innovative pedestrian networks beyond traditional streets, highlighting their design principles and impact on urban mobility.

2.1. +15 Calgary

Calgary's **+15 elevated pedestrian network**, officially launched in 1970, now stretches over **16 km** linking **86 enclosed bridges** across more than **130 buildings**, making it the most extensive skywalk system globally. By February 2018, the busiest corridors particularly the retail core north of 8th Avenue saw daily pedestrian flows of over **20,000 individuals**, with one link registering **32,689 people per day**, a **142 % increase** since 2011.

This elevated network was strategically designed to buffer users from Calgary's notoriously harsh winters, while simultaneously knitting together office towers, major retail centres (notably

The Core with its **250,000 weekly visitors**), restaurants, and public spaces. Its development was governed by the City's 1984 +15 policy, which incentivized connectivity by granting bonus floor-area to developers, a move that positioned **+15 access** as a key competitive advantage in leasing space, with linked buildings commanding higher occupancy rates.

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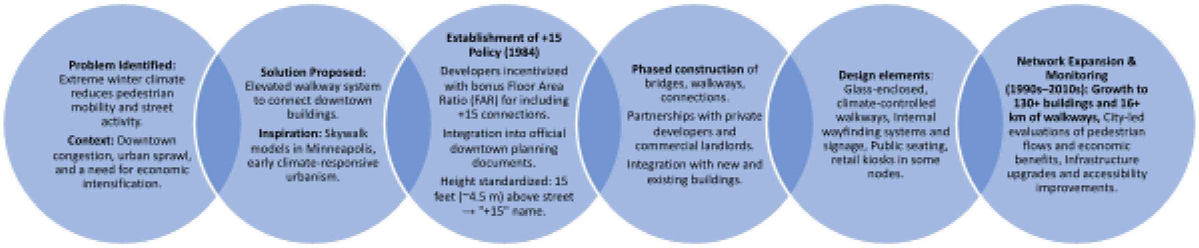
Fig 1. Exterior and Interior view of +15 bridge connecting building blocks at different places in Calgary (Source: everydaytourist.ca)

Fig 2. Left- Mobility in Downtown Calgary, Changes from 1996 to 2018 (Source: +15 network study report), Right- +15 Network (Source: 50 Back: Urban Interventions by Council on tall buildings and urban habitat)

The Design and Development Approach:



Implications for pedestrianisation research

A. **Climate adaptation:** elevated walkways ensure year-round pedestrian mobility in harsh weather.

B. **Vertical connectivity:** multi-level pedestrian systems expand access beyond street-level constraints.

C. **Street-level trade-offs:** elevated routes may reduce activity and vibrancy at ground level.

D. **Policy incentives:** development bonuses encourage integration of pedestrian infrastructure**.**

E. **Multimodal synergy:** supports walking alongside increases in cycling and transit use.

F. **Data-informed planning**: pedestrian flow data drives smarter infrastructure design.

G. **Public-private dynamics:** semi-public routes raise concerns about accessibility and ownership.

H. **Seasonal patterns:** usage trends reveal how climate shapes pedestrian behaviour over time.

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Impact: Academic assessments and planning documents (e.g., the "Plus 15 Network Study Report") consistently describe the network as a "unique part of Calgary's downtown landscape," integral to sustaining economic vitality and enabling mass pedestrian movement especially during winter but critics argue it may have unintentionally diminished street-level activity. Mobility data reinforces its impact: from **1996 to 2019**, downtown walking trips increased from roughly **31,000 to 67,000 per day** (+117%), while cycling rose **177%**, and transit trips climbed **96%** demonstrating a broad shift toward sustainable mobility supported in part by the +15 network. Moreover, at its busiest bridges, no fewer than **32,689 pedestrians** walked each day in 2018 illustrating both seasonal and year-round demand for a weather-protected network .

2.2. Underground City, Tokyo

Tokyo's underground city, particularly the network centred around Tokyo Station, exemplifies a sophisticated model of beyond-street pedestrianisation. This multi-layered subterranean system connects over 100 buildings across key districts such as Marunouchi, Otemachi, Yaesu, and Yurakucho, forming a seamless, weather-protected pedestrian zone that integrates transportation, commerce, and public space.

Stretching over several kilometres, the underground network links **major metro and rail lines (including the 18 JR lines at Tokyo Station)** and includes extensive commercial areas with shopping malls and retail corridors hosting between 180 to 350 outlets, some spanning the equivalent of three football fields. Technically, the network combines **cut-and-cover and deep shield tunnelling methods, with some segments extending up to 40 meters** underground to navigate beneath existing infrastructure.

Advanced **HVAC and fire safety systems** maintain air quality and safety, while flood resilience is ensured through waterproof gates at station entrances, capable of withstanding 15 meters of water pressure.

These measures are complemented by Tokyo's broader flood management infrastructure, such as the 6.3 km-long **Metropolitan Area Outer Underground Discharge Channel.** From an urban planning perspective, this system encourages high-density, mixed-use development and boosts economic activity through increased pedestrian dwell-time and connectivity. Tokyo's underground city thus serves as a resilient, multi-functional model for future pedestrianisation projects that transcend the limitations of surface-level street

Fig 3. Left- Complex subway system of Tokyo (Source: Official website of Tokyo metro), Right- streetscape of Tokyo YAESU Underground Street. (Source: Official website of Tokyo YAESU Underground Street)

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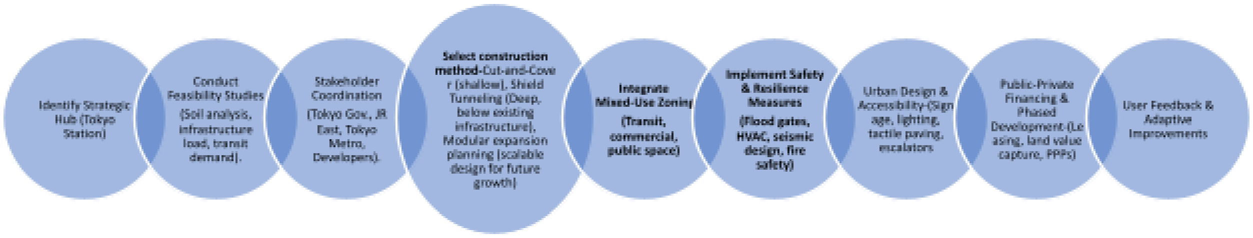
The Design and Development approach



Implications for pedestrianisation research

1. **Climate resilience:** underground networks offer flood and weather protection.
2. **Engineering models:** TBM-based tunnelling and segmental walls inform design strategies for dense, multi-level subterranean connectivity.
3. **Mixed-use activation:** commercial integration within pedestrian corridors boosts vibrancy and utility.
4. **Safety-first design:** flood-proofing, fire control, and seismic resilience are essential in underground design.

Impact: The implementation of Tokyo's underground pedestrian network has significantly enhanced urban mobility and economic vitality in the city centre. Daily pedestrian flows in key underground corridors regularly exceed several hundred thousand users, effectively alleviating congestion on surface streets and improving overall circulation efficiency. Retail areas within the network report increased foot traffic and higher sales, contributing substantially to local commercial revenue and supporting a diverse mix of businesses. The weather-protected environment has also increased pedestrian comfort and safety, leading to higher year-round usage rates compared to open-air routes. Importantly, the network's resilience features have minimized disruptions from flooding and emergencies, maintaining consistent access to transit and commercial facilities. This sustained pedestrian activity has encouraged further mixed-use development in adjacent areas, reinforcing Tokyo's model of dense, transit-oriented urban growth while reducing dependence on vehicular transport.

2.3 Minneapolis Skyway System

The Minneapolis Skyway System is one of the largest and most expansive interconnected indoor pedestrian networks in the world. Spanning over 13 miles (21 kilometres), it connects more than 80 city blocks and over 140 buildings throughout downtown Minneapolis, including major office towers, retail centres, hotels, government buildings, and sports venues such as the Target Centre. Originally initiated in 1962 with a skyway linking the NorthStar Centre and the Roanoke Building, the system has steadily expanded over the decades, particularly during the 1980s and 1990s. Each skyway is typically located on the second floor of a building, approximately 15 to 20 feet (4.5 to 6 meters) above street level, and measures between 8 to 12 feet (2.4 to 3.7 meters) in width to accommodate significant pedestrian traffic.

The Skyway is fully enclosed and climate-controlled, providing heated passageways during the winter months and air-conditioned walkways during the summer, ensuring year-round usability despite Minneapolis's extreme seasonal weather. Temperatures in winter frequently fall below -20°F (-29°C), making the system a vital piece of urban infrastructure. On a typical weekday, the Skyway serves approximately 200,000 pedestrians, many of whom rely on it to commute between offices, shops, restaurants, and transit hubs without exposure to harsh weather or vehicular traffic.

Technically, the skyways are constructed **using steel or reinforced concrete frames** and are **enclosed with glass curtain walls** that offer insulation while allowing natural light to enter. The system is well-integrated with **public transportation, offering direct access to multiple bus lines, light rail stations, and over 30 public and private parking structures, enhancing the convenience and**

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functionality of downtown Minneapolis. Economically, the Skyway has played a crucial role in supporting downtown businesses, especially retail and dining establishments that benefit from the high foot traffic. At the same time, urban planners have raised concerns about the impact of the system on street-level vibrancy, noting that it may divert activity and visibility away from the ground floor.

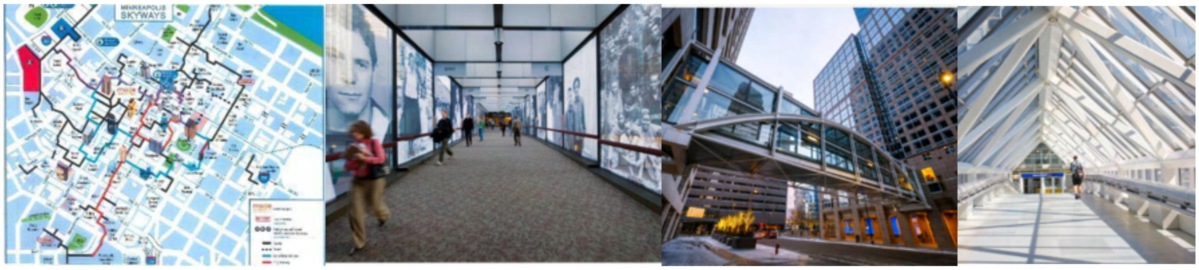
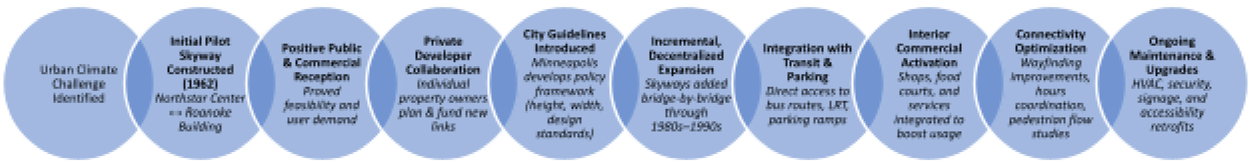


Fig 3. Left- Minneapolis Skyway Network (Source: SBNation.com), Right- Interior and Exterior views of bridges of Minneapolis Skyway Network. (Source: Getty Images)

The Design and Development approach



Implications for pedestrianisation research:

1. **Climate resilience:** Elevated, climate-controlled skyways enable uninterrupted pedestrian mobility in extreme cold and snow conditions.
2. **Modular expansion:** Bridge-by-bridge construction allows flexible, phased network growth across diverse building types and ownerships.
3. **Economic corridors:** Retail and dining integration within the network enhances mid-block activity and supports downtown business ecosystems.
4. **Accessibility planning:** Second-level placement and private access points highlight the need for inclusive, barrier-free design in elevated systems.

Impact: Since its implementation, the Minneapolis Skyway System has significantly altered pedestrian mobility and commercial dynamics in the downtown core. According to a *Star Tribune* article, certain corridors such as the City Centre-Gaviidae Common link have recorded as many as **29,230 daily users**, while the City Centre–Macy's bridge logged **18,106 pedestrians per day** following the opening of the Green Line light rail, indicating a **20-25% increase** in morning foot traffic near Nicollet Mall. A separate article in *Finance & Commerce* reported a **4% increase** in overall skyway usage between 2008 and 2009, underscoring a consistent upward trend in pedestrian volumes. On an average weekday, the entire system serves approximately **200,000 users**, many of whom rely on it for commuting between offices, shops, and transit nodes. Economically, the high foot traffic has historically supported downtown retail and dining establishments, although recent reporting by the *Star Tribune* highlights that nearly **half of skyway-level storefronts remain vacant** post-pandemic, reflecting broader shifts in work habits and commercial activity. Nonetheless, the integration of the Green Line has had a notable positive effect, with pedestrian activity increasing both on the skyway and at street level, further validating the role of transit-connected infrastructure in promoting sustainable urban mobility.

3. Comparative Analysis:

A comparative table summarizing key characteristics and design elements of the pedestrian networks in the global cities mentioned Calgary, Tokyo, and Minneapolis:

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Table 2: Summary of key characteristics and design elements of the pedestrian networks in global cities.

Category	+15 Calgary	Underground City, Tokyo	Minneapolis Skyway System
Type of Network	Elevated enclosed walkways above street level	Subterranean pedestrian network integrated with metro & malls	Elevated enclosed skyways, both indoor and semi-outdoor
Total Length / Area Covered	~18 km, 130+ buildings connected	~8 km network, 100+ buildings and major stations connected	~21 km (13 miles), over 80 city blocks
Vertical Integration	Bridges at ~15 feet above street level, connect 2nd floors	Below ground, often multi-level with subway and mall integration	Connects 2nd or mezzanine levels between buildings
Climate Control	Heated in winter, limited cooling in summer	Fully climate-controlled year-round	Heated for winter, limited cooling in summer
Connectivity Density	Dense in CBD core, linear and expanding gradually	High around key nodes (e.g., Shinjuku, Tokyo Station)	Grid-like dense layout in downtown business core
Building Integration	Offices, retail, civic buildings, parking structures	Transport hubs, malls, offices, department stores	Offices, hotels, shops, parking structures
Zoning & Incentives	Zoning bonuses for +15 connections (e.g., Floor Area Ratio)	Integrated with transit-oriented development zones	Zoning support for skyway-compatible developments
Wayfinding & Signage	Inconsistent signage; some color zones	Bilingual signs, digital maps, kiosks	Moderate signage, varies by building owner
Emergency Systems	Marked exits, fire suppression, drills coordinated by city	Advanced systems: fire, earthquake readiness, emergency phones	Fire egress, emergency lights, surveillance in corridors
Accessibility (ADA/UD)	Some inaccessible sections, ongoing retrofitting	Elevators/escalators, generally accessible, can be congested	Mostly accessible, some ramps and level issues
Pedestrian Flow Volume	Moderate: peak hours and winters busiest	Extremely high in stations: up to 500,000/day	Heavy weekday use: ~250,000 daily pedestrians
Design & Structural Challenges	Harsh winters, snow removal, limited vertical clearance	Underground congestion, earthquake risk, utility conflicts	Harsh winters, retrofitting challenges, building coordination
Security Measures	Surveillance, lighting, city-monitored patrols	24/7 CCTV, security staff, disaster training	Security by building owners, some centralized monitoring
Structural Elements	Steel/glass skybridges with thermal expansion capabilities	Waterproofing, reinforced concrete, seismic design	Steel-framed enclosures integrated with buildings
Sustainability Features	LED lighting, passive solar in select sections	Efficient HVAC, LED systems, low-energy materials	Mostly standard, some retrofits underway
Ownership & Maintenance	Mixed(public/private), coordinated via city planning dept.	Public-private mix led by metro and government entities	Private building ownership; coordinati- on via city program

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Economic Impact	Boosts foot traffic in winter, supports downtown retail	Facilitates commerce & mobility in core transit/retail areas	Vital to downtown economy in winter; retail access
Environmental Impact	Reduces car use, improves walkability	Minimizes surface-level congestion, encourages transit use	Decreases street-level traffic, encourages year-round walking
Urban Design Critiques	Weakens street-level activity; two-tier urban life	Prioritizes efficiency over social space	Reduces street life; visually sterile in some areas

4. Conclusion:

The design of pedestrian networks beyond streets has proven to be an effective way to enhance mobility, improve safety, and create vibrant urban spaces in cities across the world. While India faces significant challenges in pedestrian infrastructure, the adoption of strategies from international case studies like the +15 Calgary, Tokyo's Underground City, the Minneapolis Skyway, and New York's High Line can provide a blueprint for creating safer, more efficient, and accessible pedestrian networks. By focusing on climate-responsive designs, mixed-use spaces, security, accessibility, and connectivity, India can foster urban environments that prioritize pedestrians and enhance overall mobility. Several important factors should be considered before major interventions such as elevated walkways, underground pedestrian networks, or repurposed infrastructure are implemented: contextual analysis of the urban environment (including climate, population density), stakeholder engagement (local communities, business, and government entities), accessibility considerations (people with disabilities).

The integration of such networks with existing transport and infrastructure systems is key to maintaining smooth connectivity and minimizing disruptions during construction. Additionally, long-term **maintenance and sustainability** need to be considered, as these projects often require ongoing funding and management. Environmental impact assessments are also important, as these interventions should aim to reduce pollution, energy consumption, and dependency on cars. Lastly, the **economic feasibility** of the project should be evaluated, ensuring that the investment delivers measurable benefits in terms of mobility, safety, and economic development. Balancing these factors is essential for ensuring that such major urban interventions truly enhance the quality of life for the city's residents

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Assessment of Socio-Economic Development of Women in Affordable Housing- A case of Udaipur.

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Abstract:

Affordable housing schemes play a crucial role in addressing the housing needs of low- and middle-income populations worldwide. Beyond providing shelter, these schemes act as catalysts for women's empowerment, fostering social relations, enhancing community participation, and improving access to essential resources. Housing instability disproportionately affects women, particularly those from low-income households, as it perpetuates a cycle of poverty, restricts access to education, and limits employment opportunities. Women who experience frequent relocations or live in insecure living conditions often face heightened vulnerabilities, including economic dependence and social marginalization. Secure and stable housing plays a transformative role by providing a foundation for economic independence, enabling social mobility, and ensuring overall well-being (UN-Habitat, 2020). Women with secure housing are more likely to engage in entrepreneurial activities, pursue higher education, and participate in decision-making processes within their households and communities (Ronald & Elsinga, 2012). Furthermore, studies indicate that housing ownership significantly enhances women's financial literacy and investment behaviour, contributing to their long-term economic resilience (Chant, 2013). Affordable housing allows women to build long-term stability for themselves and their families, reducing economic vulnerability and enhancing their social capital (Moser, 2016). Affordable housing initiatives, such as India's Pradhan Mantri Awas Yojana (PMAY), have claimed to be instrumental in addressing these challenges. By promoting house co-ownership and facilitating access to essential resources, these schemes claim to strengthen women's financial and legal standing, fostering greater autonomy and security.

This study examines the multifaceted impact of affordable housing schemes on women's socio-economic development, focusing on key factors such as women's empowerment, community participation, and access to resources. This paper examines the scope of socio-economic development for women residing in affordable housing schemes at Bedwas and Nakoda Nagar, Udaipur. The research uses a questionnaire-based methodology, employing Pearson correlation and linear regression to assess key parameters.

Keywords: *Affordable Housing, Women's Empowerment, Participation, Access to resources, Socio-economic development, Udaipur.*

Introduction:

Affordable housing schemes play a crucial role in addressing the housing needs of low- and middle-income populations worldwide. Beyond providing shelter, these schemes act as catalysts for women's empowerment, fostering social relations, enhancing community participation, and improving access to essential resources. Housing instability disproportionately affects women, particularly those from low-income households, as it perpetuates a cycle of poverty, restricts access to education, and limits employment opportunities. Women who experience frequent relocations or insecure living conditions often face heightened vulnerabilities, including economic dependence and social marginalization. Secure

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and stable housing plays a transformative role by providing a foundation for economic independence, enabling social mobility, and ensuring overall well-being (UN-Habitat, 2020).

Affordable housing initiatives, such as India's Pradhan Mantri Awas Yojana (PMAY), have claimed to be instrumental in addressing these challenges. By promoting house co-ownership and facilitating access to essential resources, these schemes claim to strengthen women's financial and legal standing, fostering greater autonomy and security. According to UN-Habitat (2020), secure housing provides a crucial foundation for economic stability, enabling women to plan for their futures with greater confidence. Women with secure housing are more likely to engage in entrepreneurial activities, pursue higher education, and participate in decision-making processes within their households and communities (Ronald & Elsinga, 2012). Furthermore, studies indicate that housing ownership significantly enhances women's financial literacy and investment behaviour, contributing to their long-term economic resilience (Chant, 2013). Affordable housing allows women to build long-term stability for themselves and their families, reducing economic vulnerability and enhancing their social capital (Moser, 2016).

This study examines the multifaceted impact of affordable housing schemes on women's socio-economic development focusing on key factors such as women empowerment, community participation, and access to resources.

Location for the Study:

Bedwas Affordable Housing and Nakoda Nagar Mega Awas Yojana of Udaipur are selected for the study. These were selected based on their location just falling outside the notified Urban Area-2012, approximately 10 km from the Centre of the City.

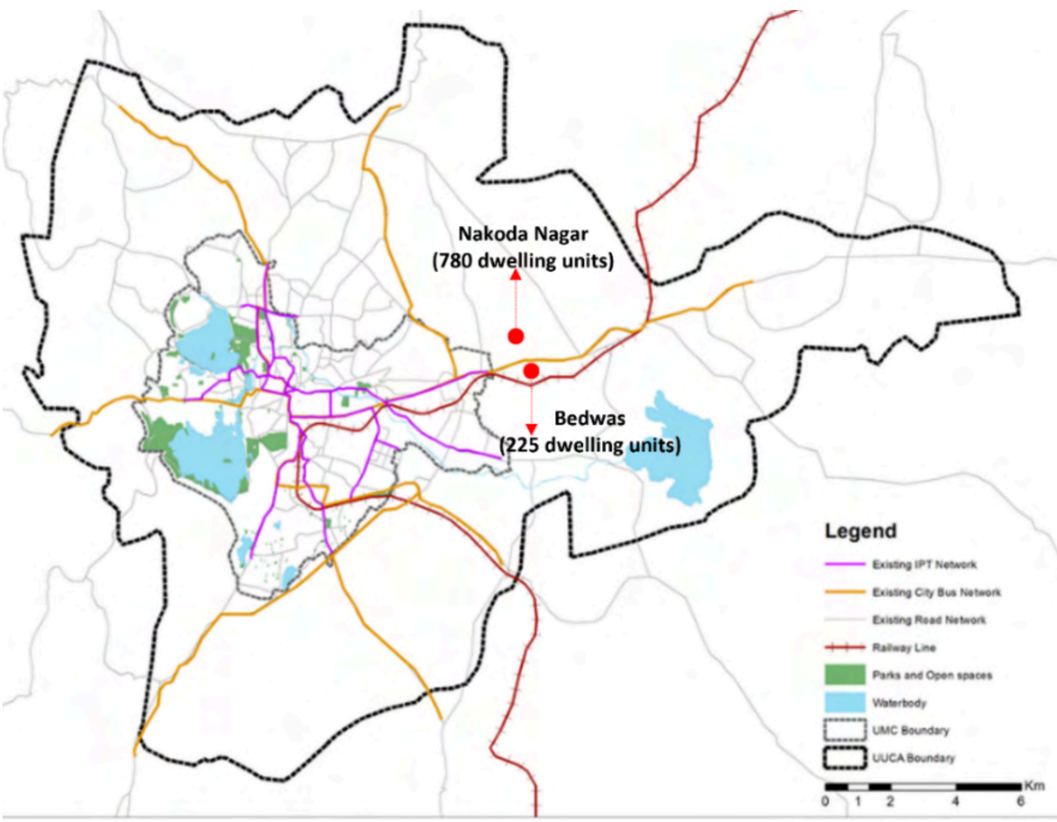

Image 1 : Map showing the location of the study area in Udaipur.

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Image 2 : Image showing the Nakoda Nagar Housing.

Image 3 : Image showing the Bedwas Housing

Image 4 : Showing Housing Conditions

Land for construction was provided by the local bodies and Rajasthan Avas Vikas & Infrastructure took the charge as Nodal Agency to ensure smooth implementation of the low-income housing units by private players. The total number of units sum up around 1005 units at both sites.

Methodology:

To achieve a balanced representation of women across different age groups, a sample of 36 women was selected from the following age ranges: 15–30, 31–45, and 46–65, in a ratio of 1:3:2. To ensure equal representation from each tower, four women were randomly selected from those who volunteered to participate in the questionnaire survey.

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Image 5 : Showing Survey being conducted on site.

The variables related to the socio-economic development of women from urban poor families were identified through a literature review of secondary sources. The data collected via the questionnaire survey were analysed to examine both inter- and intra-associations between these variables and the parameters of socio-economic development.

Pearson correlation and regression analyses were employed to assess the impact of the affordable housing environment on women's socio-economic development within the identified housing scheme. Based on their prominence in existing research, key parameters—financial independence, job opportunities, education and healthcare, community participation, and overall well-being were selected for evaluation.

Affordable Housing and Women's Socio-Economic Development in India- Excerpts from Literature:

India's housing policy has evolved from a provider-led model post-independence to an enabler approach since the late 1980s, aligning with trends in other Asian countries. Despite policy reforms, housing shortages persist, especially for the Economically Weaker Section (EWS) and Lower Income Group (LIG), with demand rising from 18.78 million units in 2012 to 29 million in 2018. Private sector incentives have addressed middle- and upper-income needs, while government initiatives—especially post-2005—target EWS and LIG through public-private partnerships. However, many mass housing projects fail due to a disconnect between user needs and state-driven planning.

Urban housing today extends beyond shelter, encompassing comfort, convenience, connectivity, and commutation. Affordability depends on income levels, unit size, and financial viability.

Affordable housing plays a vital role in women's socio-economic development by reducing living costs, increasing disposable income, and improving access to opportunities. Ravi and Krishnan (2016) and Ganguly and Mukherjee (2019) show that proximity to jobs and reduced travel times boost women's workforce participation. Alberts et al. (2016) highlight that secure housing supports women's home-based enterprises, especially when paired with economic assistance.

Social development within housing schemes fosters empowerment through self-help groups and local governance (Coelho et al., 2022), though women's needs are often overlooked in planning (Bhan et al., 2013). Schemes with community spaces enhance women's social engagement (Mohanty and Gupta, 2018).

Access to services is crucial. Poorly planned peripheral housing limits access to health and education (Sridharan, 2011), while well-integrated schemes improve well-being (Pacione, 2003; Riazi and Emami, 2018; Williams et al., 2022). Inadequate transport further restricts women's mobility and employment options (Desai and Srivastava, 2018; Rehman and Jamil, 2021).

Finally, gender disparities in housing access and decision-making persist. Women face socio-spatial marginalization due to exclusion from planning (Turner, 2007; Kuhn, 2015), underscoring the need for gender-inclusive urban housing policies.

Identification of Parameters:

Affordable housing significantly contributes to the socio-economic development of women by improving access to education, employment, health, and overall quality of life. Secure housing enables women to pursue education and skill development, which are essential for financial independence and long-term career advancement (UNESCO, 2021). Proximity to job markets and affordable living costs enhance employment opportunities and economic stability, helping to reduce poverty (World Bank, 2021). Adequate housing also positively affects women's health by providing safe living conditions, clean water, and sanitation, all of which influence well-being and productivity (WHO, 2020). Gender-inclusive housing policies ensure fair access to resources, decision-making, and mobility, promoting inclusive economic growth (UN Women, 2019).

Community participation plays a vital role in this process by fostering trust, social capital, and women's involvement in housing-related decisions. Strong community networks support cooperation, mutual assistance, and access to employment, financial help, and essential services (Putnam, 2000; Bourdieu, 1986). Participation in community programs ensures that women's needs are addressed in urban planning, thereby improving access to education, healthcare, and childcare (Narayan, 1999). Access to material, financial, and social resources further enhances women's economic opportunities. Secure housing with adequate infrastructure provides a foundation for income-generating activities and educational pursuits (UN-Habitat, 2020), while financial tools such as microfinance and subsidies ease housing affordability and free up resources for entrepreneurship or children's education (Chant, 2016).

Social resources, including community support systems, improve resilience and access to job opportunities and safety nets (Moser, 2018). The location of housing also influences women's mobility and economic participation; proximity to services like transport, healthcare, and education is key to breaking cycles of poverty (World Bank, 2021). Without these enablers, women from low-income groups remain vulnerable to social exclusion and economic instability. These parameters collectively offer a comprehensive framework to assess the impact of affordable housing schemes on the socio-economic empowerment of women.

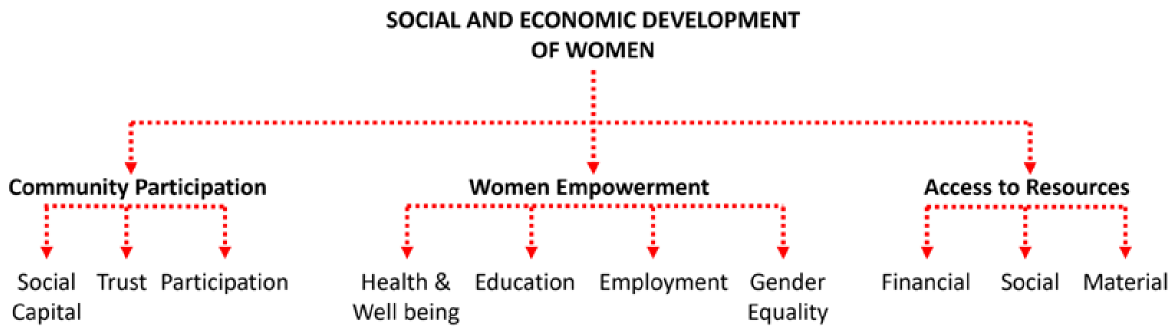

Image 6 : Parameters & Indicators for Socio- Economic Development of Women in Affordable Housing.

Results & Discussion:

The correlation and regression analysis emphasize the crucial role of community participation, access to resources, and women's empowerment in driving the socio-economic development of women in affordable housing environments.

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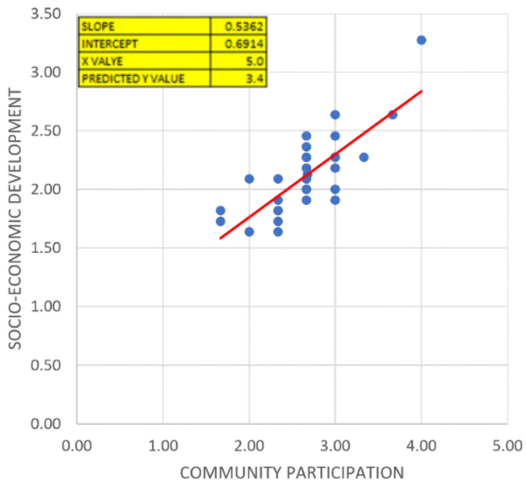

Image 7 : Regression Graph- Socio-Economic Development And Community Participation.

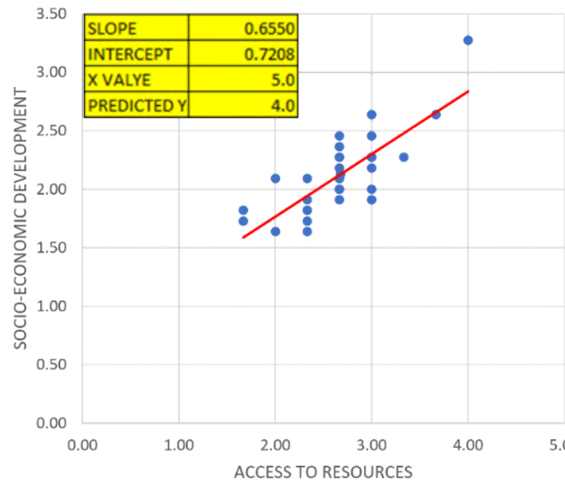

Image 8 : Regression Graph- Socio Economic Development and Access to Resources.

The survey data revealed a strong positive correlation between community participation and socio-economic development r(34)= 0.8, emphasizing its crucial role in fostering collective decision-making, strengthening social networks, and enhancing access to opportunities (Putnam, 2000). Currently, community participation at the surveyed location is at 53.6%, while socio-economic development is at 42.6% which can be understood from the mean values of responses of surveyed women [Mean(community participation)=2.68 & Mean(socio-economic development)=2.13) however, if community participation reaches its full potential, socio-economic development is predicted to rise to 68%. This aligns with research suggesting that inclusive community involvement leads to greater economic mobility, improved safety, and better access to employment and education (Moser, 2018).

Access to resources, such as financial services, transport, and social infrastructure, is another key determinant of socio-economic development. The analysis shows a strong correlation [r(34)=0.7] between resource accessibility and development, highlighting that women in affordable housing schemes currently have limited access [43% understood from Mean (**Access to resources**)= 2.15].

Regression analysis predicts that maximizing resource accessibility could elevate socio-economic development to 80%. This is supported by studies indicating that financial inclusion, transportation connectivity, and proximity to essential services significantly impact women's ability to engage in the workforce and access healthcare and education (Chant, 2016; UN-Habitat, 2020). Furthermore, land-use maps and Google satellite imagery confirm that these housing sites are surrounded by agricultural lands—both usable and barren—leading to poor urban integration. The absence of well-developed commercial, industrial, and service-oriented zones nearby further diminishes housing demand.

Google map Showing the immediate surrounding of the Housing Location at Bedwas

Google map Showing the immediate surrounding of the Housing Location at Nakoda Nagar

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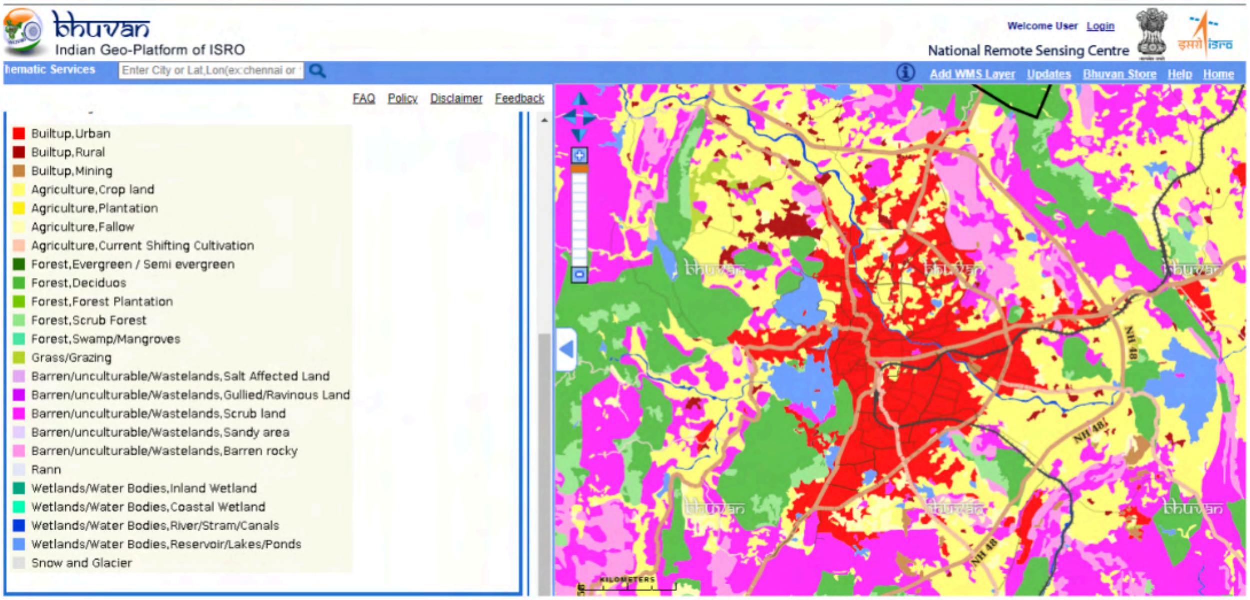

Image 11 : Showing Map Depicting Poor Land Use Around the Housing Site.

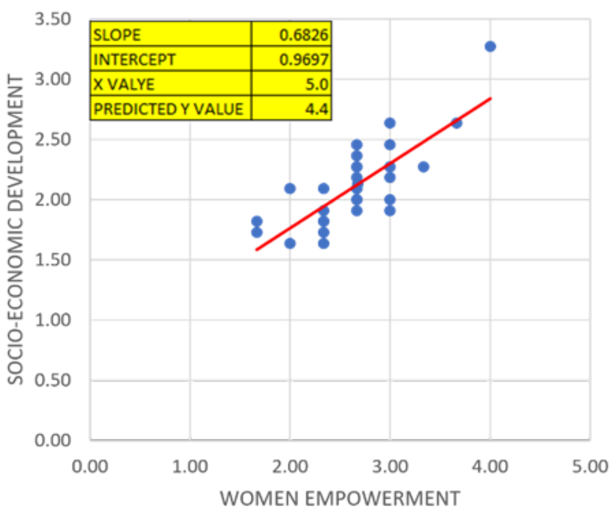

Image 12 : Regression graph- Socio- Economic Development and Women Empowerment

Women's empowerment emerges as the most critical factor, with a very strong correlation [r(34)=0.9] with socio-economic development, meaning efforts to enhance empowerment will have the most substantial impact. Currently, limited empowerment opportunities 33.8%, reflected by a low mean value for Women Empowerment (Mean = 1.69, only) are restricting socio-economic progress.

This limitation is further evidenced by the trend of women shifting to home-based work setups, as observed during the survey. These setups negatively impact quality of life, as they require sacrificing already scarce livable space. Most of these housing units do not exceed 28 sq.m in area, and accommodating workspaces within them leads to significant spatial constraints and overcrowding.

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Image 13 : Showing the condition of Home Workers.

The regression analysis suggests that maximizing empowerment initiatives could boost development to 88%. Literature affirms that empowerment through skill development, leadership opportunities, and access to credit fosters greater economic independence and improved living standards for women (Kabeer, 2005; World Bank, 2021). Additionally, women's empowerment is strongly linked to both **community participation [r(34)=0.6]** and **access to resources [r(34)=0.4]**, reinforcing that while community engagement fosters networks and collective action, resource accessibility serves as a catalyst for individual empowerment.

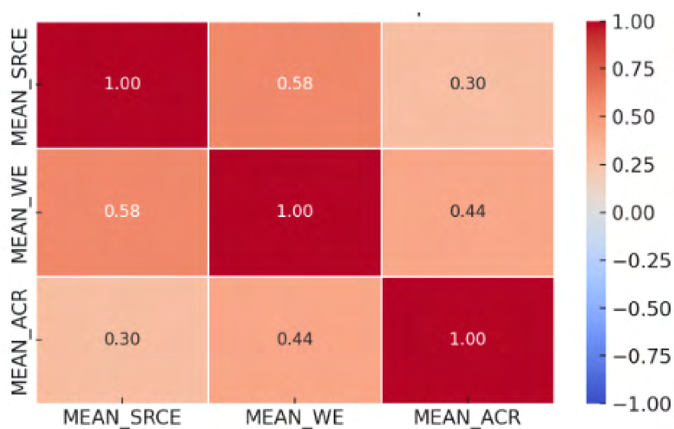

Image 14 : Correlation Heat Map within variables.

Furthermore, within groups, the moderate correlation [r(34)=0.3] between community participation and access to resources suggests that while both factors contribute to socio-economic development, resource accessibility remains a more personalized experience, whereas community participation enhances shared experiences.

Conclusion:

This aligns with research indicating that community-driven housing models, where women are actively involved in decision-making, result in better economic outcomes and long-term stability (UN Women, 2019).

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The limited effectiveness of community participation, access to resources, and women's empowerment in driving socio-economic development is largely due to the peripheralization of affordable housing schemes. These schemes are often located on the urban fringes, far from city centers, which restricts access to employment opportunities, essential services, and social networks. This spatial isolation significantly limits women's mobility, economic engagement, and participation in community initiatives, thereby impeding their socio-economic progress. The success of affordable housing in fostering women's development depends not only on affordability but also on the presence of supportive surrounding land uses, including commercial areas, educational institutions, healthcare facilities, and efficient public transportation.

Without integrated urban infrastructure, even cost-effective housing creates economic and social barriers that undermine women's financial independence and reinforce vulnerability. To truly support women's empowerment, housing policies must go beyond cost considerations to prioritize strategic site selection, accessibility, and mixed-use development. Locating housing near economic hubs and public services—combined with strong community networks—can significantly improve women's economic participation and social inclusion. Moreover, integrating transport links, employment opportunities, and public amenities into housing plans can enhance women's autonomy, safety, and quality of life.

Ultimately, the findings highlight that strengthening community participation, access to resources, and women's empowerment is essential for the success of affordable housing schemes. A gender-responsive approach to housing policy—rooted in inclusivity, accessibility, and opportunity—can break the cycle of poverty and contribute to sustainable and equitable urban development.

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ISBN 978-93-342-4408-3

SMART AND GREEN RETROFITTING IN EXISTING BUILDINGS

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Abstract

Retrofitting existing buildings into smart and green buildings under the aspects of energy, water, and materials along with the occupant well-being, environmental performance, and smart technology should be taken into account. In this Paper, green and smart strategies and techniques have been recommended according to the criteria of LEED and GRIHA to improve the smart and green performance of the buildings which evaluates the environmental and economic impacts. Nowadays there are a lot of energy resource crises occurring due to the increase in population. So, Architects and Engineers play major roles in construction economy to help the industry by constructing smart and green structures which have no effect on the environment. If we rebuilt the existing buildings, it would take more money and resources for construction. Smart and green retrofitting of existing buildings offers a healthy solution for our environment.

INTRODUCTION

There are a lot of energy crises due to the increase in population. Nowadays, new construction is constructed smart and green by considering the factors that should not affect the environment and most importantly to reduce carbon footprint and work on the crises.

Our focus is less on the construction that was done without taking smart and green strategies into account, which could have helped the building reduce its carbon footprint. As an architect or person we have a duty to deal with existing buildings to make them green and smart to save energy and make a building stand up to nowadays buildings.

So this research has focused on the strategies and techniques that can be used in the existing building to create it more energy efficient and can reduce carbon footprint.

Aim: To explore the techniques used to retrofit the existing building into a smart green building.

Objectives:

- To study about smart and green buildings.
- To study, about retrofitting.
- To investigate techniques that can help in smart and green building retrofitting.
- To recommend strategies for smart and green building retrofitting.

Scope:

- The scope of this research is to retrofit the existing buildings into smart and green buildings which leads to minimizing energy consumption and reducing the impact of carbon footprint on the environment.
- This research covers smart techniques and criterion of GRIHA (Energy Optimization, Occupant Comfort, Water Management, Waste Management, Sustainable Building Materials, Sustainable Site planning) to retrofit existing building into smart and green.

Limitations:

- Did not get permission to survey the building for the case study due to security purposes.

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- There are not many existing buildings that have been retrofitted into smart and green buildings.
- This research covers only techniques which make a existing building smarter and green.
- In this research active techniques are not explained.

LITERATURE STUDY

What are smart buildings?

Smart buildings aim to enhance the occupant's comfort while reducing resource consumption. It is designed for efficiency, comfort, and sustainability with the help of integrated systems and automation systems for optimized functions like energy usage, security, and occupant comfort. Its main features are IOT sensors, automation controls, energy management, data analytics, and remote monitoring. A smart building system provides the occupants with productive and comfortable conditions by responding to their requirements and enhancing the workplace environment.

Concept of smart building:

The concept behind smart buildings is designed for occupants to feel comfortable and automate buildings by using automation systems to control individual areas such as security, lighting, energy efficiency, maintenance, operation, HVAC, communication, and IT. It is designed to make buildings smarter, more user-friendly, safer, more cost-effective, and easier to maintain.

What are green buildings?

A green building, also known as a sustainable building It is designed by focusing on minimizing its environmental impact while maximizing resource efficiency and occupant well-being. The idea is to help our environment as well as to work on human comfort, energy efficiency, safety, well-living life, and eco-friendly, etc.

Concept of green building:

The main concepts of green building are reducing energy consumption, conserving water, sustainable-friendly materials, and occupant comfort.

A green building gets certified with the help of incorporating strategies in their buildings. There are rating systems and certifications like GRIHA, LEED etc.

Passive Strategies: They are the strategies that utilize the site elements that are present naturally for free to keep buildings comfortable without the need for purchased energy.

Active Strategies: They are the strategies that use purchased energy to keep buildings comfortable.

Credit Assignment (LEED & GRIHA):

LEED (Leadership in energy and environmental design)

It is a widely recognized and globally used green building certification system. Developed by the U.S. Green Building Council, it provides a framework for building owners and operators to design, construct, operate, and maintain buildings in an environmentally sustainable and energy-efficient manner.

LEED rating system: Divided into 4 categories.

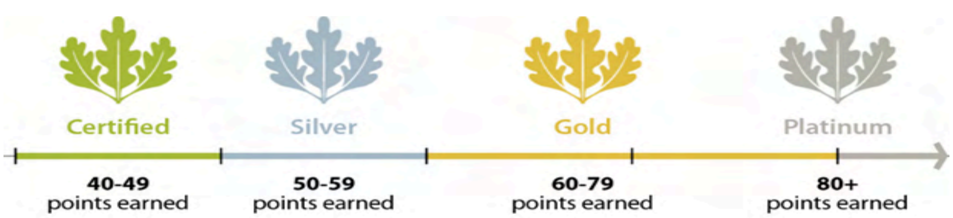

Figure 1 LEED Rating System (Source: LEED)

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GRIHA (Green Rating for Integrated Habitat Assessment):

It is an Indian green building rating system and certification which promotes sustainable and environmentally friendly construction practices in buildings. It focuses on factors regarding energy efficiency, water conservation, waste management, and indoor air etc. There are a total 11 sections and 30 Criteria. GRIHA certification is issued by TERI (The Energy Research Institute).

Percentile threshold	Achievable stars as per GRIHA v. 2019
25–40	★
41–55	★★
56–70	★★★
71–85	★★★★
86 and more	★★★★★

Figure 2 GRIHA Rating System (Source: GRIHA)

Retrofitting: Retrofitting upgrades existing buildings for safety, efficiency, and sustainability without full reconstruction. It includes structural improvements, insulation, and system upgrades.

Strategies for smart retrofitting:

1. **IOT Sensors:** It is a network of sensors that are installed throughout the building that allows concurrent monitoring of environmental conditions like temperature, humidity, and occupancy.
2. **Automation and Control:** They control functions like lighting, and HVAC based on data that the sensor collects. This ensures that energy is used efficiently and that occupants are comfortable.
3. **Energy Management:** Smart buildings focus on optimizing energy consumption.
4. **Building Management Systems (BMS):** BMS works as the central control system for all building systems. They enable remote monitoring, scheduling, and control of HVAC, lighting, security, and other systems.
5. **Security and Access Control:** In buildings use biometrics, access cards, and video surveillance to ensure the safety of occupants. Users can control the security system from their smart phones.
6. **Waste Management:** Smart waste management systems use sensors to optimize waste collection and recycling efforts, reducing operational costs and environmental impact.

Strategies for green retrofitting:

1. **Energy Efficiency:** Focus on reducing energy consumption through better insulation and energy-efficient systems.
2. **Water Conservation:** Use of water-saving fixtures and rainwater harvesting.
3. **Sustainable Materials:** Choose sustainable and low-toxicity materials.
4. **Waste management:** Reduce construction waste through recycling and efficient practices.
5. **Occupant Comfort:** Prioritize healthy indoor environments with good ventilation and low-VOC materials.

Parameters identification for case study

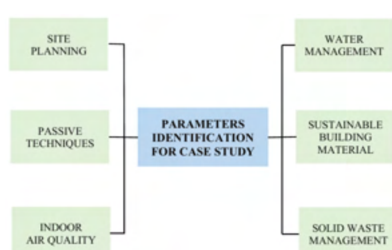

Figure 4 Parameters for case studies (Source: Author)

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CASE STUDIES

Parameter	ITC green centre	Paharpur business centre	New Maharashtra sadan	Suzlon one earth	UN house	Comparison and analysis
Site parameter	Building facing: north side Heat Island	Alternative Strategies: Solar Films	Building water consumption reduced	Minimum Site Disturbance	Heat island effect	Comparison of lighting, pollution, etc.
Energy optimization (Active Strategies)	HVAC: AHU, VFD Hot Water: Solar.	Solar Films. Building façade	Replaced old appliances...	Energy efficient HVAC. Sensor-based lighting	Solar panels... Photovoltaic system...	Most used HVAC and efficient electrical appliances
Water management	Efficient Landscaping... Water Use Reduction...	Sensor Taps... Free Water for Gardening	Usage reduced 47.14%...	Rain Water Harvesting.	Efficient fixtures... Rainwater harvesting	Use of SPT Treated Water... Storm water use
Sustainable Building Materials	Stored recyclables. Recycled Content.	AAC Blocks, Certified Wood	Used fly ash blocks...	Used regional materials...	Low ODP materials... Pest control chemicals.	Used recycled and renewable content
Human Health and Comfort	Indoor air quality, Low Emitting Materials...	Indoor air quality, Toxin-removing plants...	Indoor comfort... Humidity and noise control	Use of low emitting materials... Natural views...	Signage, daylight Air quality	Common emphasis on indoor air quality
Innovation Design	Green Education... Workshops...	Green energy resource.	Green housekeeping Zero waste	Green education. Zero waste.	Green education. Zero waste policy.	Innovation in zero waste policy across buildings
Solid Waste Management	FAB system. Waste segregation.	Segregated waste	Managed organic manure.	Color coded bins.	Color coded bins.	All used segregation and waste management
Smart Techniques	Access control... Motion sensors.	Sensor lights. Fire alarms.	Sensor based lighting. Automation	Sensor taps... Building Automation.	24 hr security... CCTV...	Use of BAS and automation in all buildings

CASE STUDY 1 - ITC GREEN CENTRE

- Energy consumption before = 35,00,000 kWh/year
- Energy consumption after = 20,00,000 kWh/year
- Annual Energy Savings Rs. 9 Million

CASE STUDY 2 - PAHARPUR BUSINESS CENTRE

- Energy consumption before = 896251kWh/year
- Energy consumption after = 445280 kWh/year
- Annual Energy Savings Rs. 6 Million

ISBN 978-93-342-4408-3

CASE STUDY 3 - NEW MAHARASHTRA SADAN

- Energy consumption before = 598410kWh/year
- Energy consumption after = 248570 kWh/year
- Annual Energy Savings Rs. 2.5 Million

CASE STUDY 4 - SUZLON ONE EARTH, PUNE

Energy consumption = 4 MW(Megawatt) 92.3% (Net zero Building)

CASE STUDY 5- UN HOUSE

- Energy consumption before=49841 kJ/year
- Energy consumption after=24453 KJ/year

RECOMMENDATIONS

1. **Site Parameters**
    - Use reflective roof paint to reduce heat gain and HVAC load.
    - Install open-grid pavement for 50% of parking areas to minimize heat islands.
2. **Pollution Reduction**
    - Limit outdoor lighting to reduce light pollution and preserve the night sky.
3. **Public Transport Promotion**
    - Provide EV charging stations and facilities to encourage sustainable transport.
4. **Energy Optimization**
    - Use façade mesh and solar films to reduce heat gain.
    - Replace outdated appliances with BEE-rated equipment.
    - Install sensor-based lighting, efficient ventilation, and solar panels.
5. **Water Management**
    - Collect and reuse stormwater.
    - Install drip irrigation systems and use 100% treated STP water for landscaping.
    - Incorporate water-saving fixtures and efficient landscaping.
6. **Sustainable Materials**
    - Use regional, recycled, and renewable materials.
    - Minimize construction waste and promote reuse.
7. **Human Health & Comfort**
    - Ensure good indoor air quality with air washers and toxin-removing plants.
    - Use low-emission materials and maximize natural light and ventilation.
8. **Innovative Design**
    - Promote awareness, on-site renewable energy, green housekeeping & zero waste policies.
9. **Smart Techniques**
    - Integrate BAS for building automation.

ISBN 978-93-342-4408-3

- Use motion-sensor lighting, CCTV, fire safety systems, access controls for security and efficiency.

CONCLUSION

The study concludes that smart and green retrofitting of existing buildings is a highly effective and sustainable approach to addressing contemporary environmental and energy challenges. By analysing various case studies and evaluating multiple retrofitting techniques, it is evident that integrating intelligent systems with environmentally responsible strategies can significantly improve a building's performance in terms of energy efficiency, occupant comfort, and environmental impact.

Retrofitting not only reduces the need for new construction thereby conserving resources and minimizing waste but also extends the functional life of existing structures. The implementation of sensor-based technologies, renewable energy sources, water management systems, and sustainable materials proves essential in transforming conventional buildings into high-performing, future-ready spaces.

This research highlights that the combined application of smart technologies and green building principles can result in a dual benefit: operational efficiency and environmental sustainability. Therefore, smart and green retrofitting stands out as a critical strategy in the pursuit of sustainable urban development and should be prioritized in future planning and architectural interventions.

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ISBN 978-93-342-4408-3

Assessment of Redevelopment of Chandni Chowk Street

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Abstract

This research paper critically evaluates the redevelopment of Chandni Chowk, one of Delhi's oldest and most iconic commercial and heritage corridors. The project, initiated by the Delhi government, aimed to resolve chronic urban issues such as traffic congestion, infrastructural decay, and loss of heritage character, while enhancing pedestrian accessibility and urban aesthetics. The study assesses the effectiveness of these interventions in achieving a balance between modern urban infrastructure and historical preservation. Using primary surveys, interviews, and site observations, supported by secondary data, the research explores the impact on pedestrian experience, local commerce, street vendors, and heritage elements. The findings highlight both the achievements and the challenges of the redevelopment, offering lessons for future urban renewal in culturally sensitive areas.

Keywords: Chandni Chowk Redevelopment, Urban Mobility, Heritage Conservation, Pedestrian Accessibility, Street Vendors, Economic Impact

INTRODUCTION

Chandni Chowk, established in the 17th century by Shah Jahan and designed by JahaChandni Chowk, established in the 17th century by Shah Jahan and designed by Jahanara Begum, holds immense historical, cultural, and commercial significance in Delhi. Over time, the area faced severe urban challenges including over-congestion, deteriorating infrastructure, pollution, and loss of heritage identity. To address these issues, the Delhi government launched a large-scale redevelopment initiative aimed at enhancing the pedestrian experience, improving infrastructure, and reviving the historic ambiance. This paper assesses the success of the project, particularly its impacts on mobility, heritage conservation, and socio-economic dynamics.

Objectives:

- Evaluate the impact on pedestrian movement and traffic management, including how restricted vehicular access and wider footpaths affect flow and safety.
- Analyze changes in local business and informal vending, especially how enforcement and redesign influenced shopkeeper revenues and vendor access.
- Assess conservation strategies for heritage elements such as façade treatments and traditional materials.
- Examine sustainability and environmental improvements through infrastructure upgrades like drainage, lighting, and signage.

LITERATURE REVIEW

Urban redevelopment in historic districts is a complex yet essential process. It often involves:

- **Heritage Conservation:** Balancing preservation with modernization. This involves maintaining the traditional architecture and visual character while introducing contemporary infrastructure.
- **Pedestrianization:** Prioritizing walkability in dense, heritage-rich areas. The concept focuses on reducing vehicular traffic and enhancing the pedestrian realm for safety and convenience, especially in culturally sensitive areas.
- **Environmental Sustainability:** Integrating green infrastructure and efficient utilities. Adoption of stormwater management, smart lighting, and environmentally friendly materials contribute to

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long-term sustainability.

Case References:

- **Times Square, NYC and La Rambla, Barcelona** have shown successful urban renewal while preserving historical essence.
- In India, projects like **the Golden Temple Heritage Street and Kashi Vishwanath Corridor** serve as precedents in managing spiritual, commercial, and pedestrian needs within heritage contexts. Both Amritsar and Varanasi projects balanced religious tourism and heritage aesthetics with infrastructure upgrades.

CASE STUDIES

Parameter	Chandni Chowk, Delhi	Golden Temple, Amritsar	Kashi Vishwanath, Varanasi
Heritage Significance	Mughal-era commercial spine	Sacred Sikh site	Sacred Hindu site
Urban Challenges	Congestion, unregulated vendors	Encroachments, visual clutter	Dense housing, lost river link
Intervention Type	Streetscape & traffic restructuring	Pedestrianization & façade improvement	Corridor creation & open space
Pedestrian Focus	Yes	Yes	Yes
Restoration Efforts	Select façades and street elements	Traditional materials for façade work	Restoration of hidden temples
Stakeholder Involvement	Govt, traders, public	Govt, SGPC, locals	Govt, temple trust
Design Strategy	Streetscape & service integration	Urban aesthetics and heritage feel	Heritage exposure and access
Tourism & Pilgrimage	Moderate	High	Very High

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CASE STUDY: CHANDNI CHOWK, DELHI

Pre-Redevelopment Issues

- **Traffic Congestion:** Mixed pedestrian and vehicular movement led to severe congestion, making the street unsafe and dysfunctional, highlighting the urgent need for pedestrian prioritization.
- **Poor Infrastructure:** Exposed overhead wires, ineffective drainage, and broken pavements reflected urban decay, diminishing the quality of both public realm and heritage appeal. **Vendor Encroachment:** Unregulated vending practices narrowed movement corridors and obstructed visual access to shops and heritage buildings, reducing spatial efficiency and aesthetics.
- **Heritage Neglect:** Centuries-old facades and structures suffered from pollution and neglect, undermining the street's historic character central to this study.

Redevelopment Objectives

- **Decongestion Measures:** Introduction of restricted vehicular hours aimed to reduce traffic pressure and enhance pedestrian safety, aligning with walkability goals in heritage zones. **Infrastructure Modernization:** Underground cabling, wider footpaths, and smart lighting aimed to upgrade basic services while preserving historical context.
- **Heritage Preservation:** The use of traditional materials and techniques in façade restoration reflects a conservation-driven approach to redevelopment.
- **Urban Design Enhancement:** Improving walkability through uniform design elements was intended to create a cohesive and culturally sensitive public space.

Key Features Implemented

- **Timed Vehicular Control:** Vehicles were limited during day hours, supporting uninterrupted pedestrian flow, which aligns with successful pedestrianization strategies in historic districts.
- **Pedestrian Pathways:** Dedicated, shaded walkways and resting areas aimed to improve user comfort and mobility, especially for tourists and elderly visitors.
- **Façade and Design Integration:** Restoration efforts included harmonized signage and furniture, creating a unified architectural identity across the street.
- **Environmental Infrastructure:** Waste and water systems were upgraded to ensure sustainable functioning of the public realm without compromising heritage aesthetics.

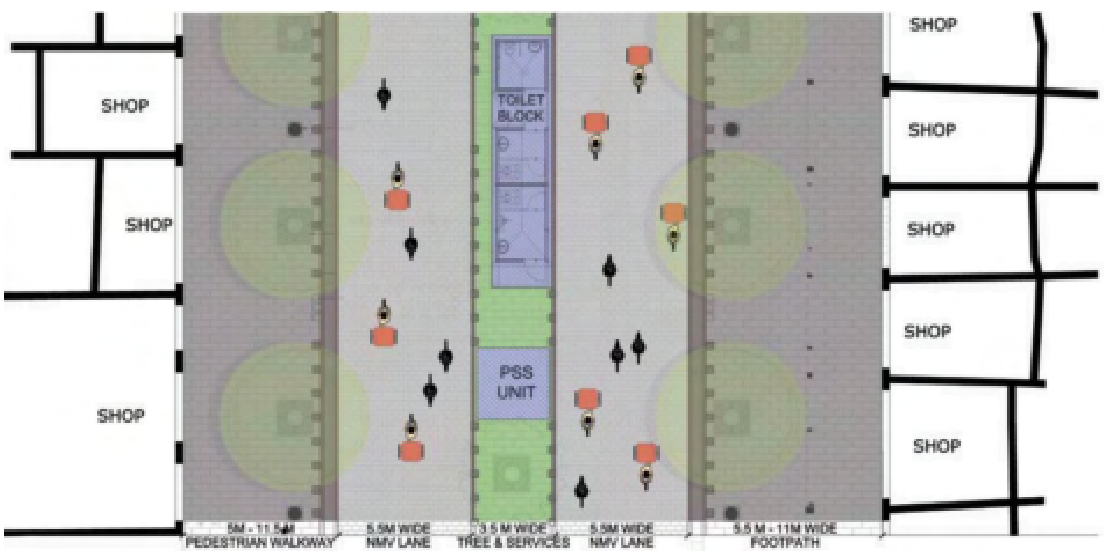

Fig 01. Proposed Plan of Chandni Chowk by PSDA Source: ***<u>https://srdc.delhi.gov.in/en/srdc/redevelopment-chandni-chowk</u>***

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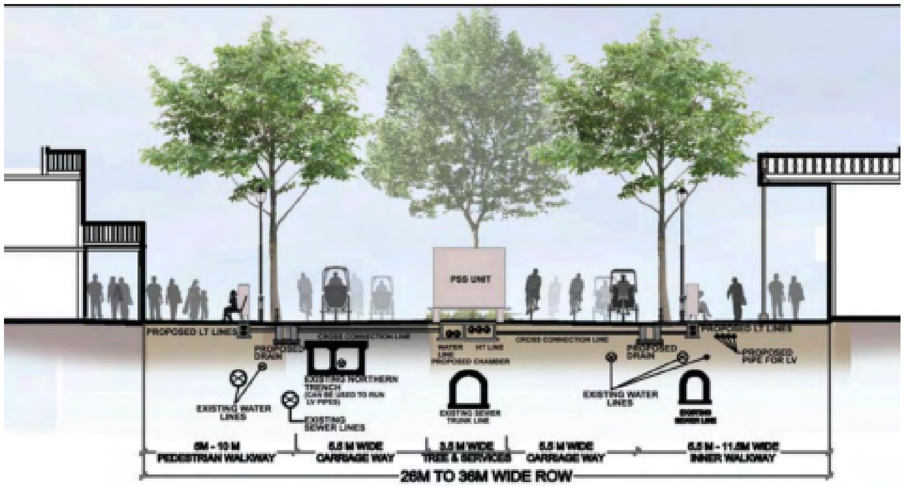

Fig 02. Proposed Section (Rendered) of Chandni Chowk by PSDA Source:
https://srdc.delhi.gov.in/en/srdc/redevelopment-chandni-chowk

Fig 03. Proposed View of Chandni Chowk by PSDA Source:
https://srdc.delhi.gov.in/en/srdc/redevelopment-chandni-chowk

FINDINGS & DISCUSSION

Positive Outcomes

- **Improved Pedestrian Experience:** Redevelopment created a safer, cleaner, and more navigable environment, as reflected by 70% of surveyed users reporting greater comfort.
- **Enhanced Visual Appeal:** Uniform façade treatments revived the historic look of the street, reinforcing the site's cultural identity.
- **Urban Comfort and Mobility:** Shaded seating, trees, and organized pathways improved microclimatic comfort and urban legibility.
- **Boost in Tourism:** Cleaner streets and heritage restoration attracted more tourists, validating the project's goal of enhancing heritage-based economic activity.

Challenges

- **Vendor Displacement:** Enforcement of vending zones led to the exclusion of many informal vendors, revealing gaps in inclusive planning—a key concern raised in your research.
- **Accessibility Issues:** Lack of PWD-friendly facilities and toilets suggests that universal design principles were not fully integrated.
- **Traffic Regulation Delays:** Inconsistent control during implementation caused confusion, reflecting the importance of management and monitoring in post-redevelopment phases.

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- **Heritage Commercialization:** Standardization of shopfronts leaned toward tourist-focused aesthetics, risking loss of authenticity—an important tension between revitalization and commercialization noted in heritage planning.

Survey Insights

- **Pedestrian Safety (70%):** A majority of pedestrians reported feeling safer after the redevelopment, highlighting the success of improved walkability, dedicated pathways, and separation from vehicular movement—key goals of the project.
- **Shopkeeper Disruption (58%):** Over half of the shopkeepers experienced disruptions in traditional customer movement due to altered access points, footpath widening, and restricted vehicle entry, indicating unintended economic side effects of spatial interventions.
- **Tourist Satisfaction (65%):** Most tourists appreciated the enhanced cleanliness, organized circulation, and visual coherence of the redeveloped street, reflecting positive reception of heritage-led public realm improvements.

CONCLUSION

The Chandni Chowk Redevelopment Project has made significant strides in improving infrastructure, pedestrian access, and visual quality. However, the project reveals critical gaps in inclusive planning, especially regarding street vendors and accessibility. A context-sensitive approach, combining modernization with cultural integrity, remains essential for sustainable urban regeneration in heritage zones.

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ISBN 978-93-342-4408-3

DeepCrackVision: Real-Time Structural Integrity Assessment through CNN-YOLO Hybrid framework for Autonomous crack detection in Aging Infrastructure.

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Abstract

Structural safety is a crucial factor in civil engineering, particularly for aging structures where cracks that are not easily observed could produce failures leading to safety risks. Conventional inspections are time consuming and prone to human error. This research proposes an AI-based system composed of Convolutional Neural Networks (CNN) to extract features from the data set and YOLO for real-time crack detection. CNN can identify patterns in the crack patterns. YOLO can do the crack detection, in a fast, and cost-effective manner while simultaneously monitoring a wide area. The hybrid model is also advantageous because it is a good balance between accuracy and speed, which is useful for monitoring urban infrastructure. By implementing drone inspections with the accompanying infrared imaging, deep or hidden cracks may be identified. The goal of this innovative approach would be to automate the process of structural health monitoring, reduce maintenance costs, improve safety, and extend the life cycle of structures.

Keywords: *Structural Crack Detection, Autonomous Structural Assessment, Real-Time Infrastructure Monitoring*

INTRODUCTION

The integrity of civil infrastructure is vital for safety and sustainable management. Buildings, bridges, and other critical infrastructure have aged and deteriorated due to service loading and extreme weather making cracks more likely to develop which can lead to an unanticipated catastrophic collapse, which may lead to public and property damage, catastrophic economic loss, and risk to health & safety if unseen. According to the American Society of Civil Engineers (ASCE), there is at least an estimate that over 40% of U.S. infrastructure, such as bridges and buildings, were constructed over 50 years ago, and ASCE further estimates that maintenance will account for over $1 trillion annually by 2030 [1]. The global case is similar, especially when considering urban metropolises with aging infrastructure and compact populations. Traditional crack detection is purely visual and includes the use of a manual inspection process which takes time and labour, and relies purely on subjective judgement, therefore small, shallow, or internal cracks are likely to be missed due to unavoidable human error. Hence the need for automated approaches that are trustable, sustainable, can be applied in real time, and can also continuously monitor as part of a holistic safety and civil infrastructure health maintenance strategy.

Crack detection has, historically, been a vital area of concern in civil engineering, with traditional approaches using visual inspection, ultrasonic testing, and radiographic techniques. While these conventional methods are partially successful in laboratory-style environments, with long set-up times and costly precision equipment - not to mention the interpretation and visual aspects, concentration, and user experience of the operator - these approaches can be impractical when one considers broad-scale or real-time implementation. The practical limitations to scale and cost remain a major barrier for technically available methods to overcome. Traditional forms of physical inspections and methods of analysis are highly subjective, with different inspectors experiencing variations based on the inspection setting. In more recent years, more advancements of nondestructive testing (NDT) methods, such as acoustic emission, and infrared thermography have reached maturity in terms of sensing and computational aspects, but has created a technology gap to address scale issues for the engineer in the real world. Emerging technology using artificial intelligence (AI) and computer vision also represent a revolutionary opportunity to change the nature and weaknesses of existing approaches and technology, and especially perception in regards to structural health monitoring (SHM).

Deep learning has enabled significant advances in automated image analysis, most notably through Convolutional Neural Networks (CNNs). CNNs are particularly adept at discovering hierarchical spatial patterns within images, which facilitate the ability to identify complicated patterns, i.e. locating cracks in a structural surface. Research has shown that CNNs can differentiate between crack severity, distinguish cracks from non-crack features, and improve images through denoising structural images [3]. Despite its advantages, the use of CNN based models requires considerable computational resources (and power to run). For this reason, CNNs remain unfeasible for quick analysis on resource contaminated platforms, such as drones or embedded systems for monitoring infrastructure and superstructures. Recent work has focused into finding light weight object detection frameworks, wherein we rely less on processing power, for example You Only Look Once (YOLO), which focuses on faster processing speed while maintaining accuracy [4]. YOLO represents an example of a single staged detection method. In this fashion the YOLO architecture is designed for quick localization and classification of objects, so that once, we can apply deep learning to real-time object analysis in the field.

Despite this progress, a notable research void remains for the joint utilization of the strong feature extracting capabilities of CNNs and the real-time detection speed of YOLO for structural crack feature detection. All existing papers either study high-accuracy CNN models with great/computational effort or lightweight detection architecture but sacrifice accuracy for complex crack features. There are few notes which examine how to marry these approaches to develop an understanding of high accuracy and widespread real-time building monitoring for large-scale urban infrastructure. Lastly, the role of combining multimodal data (e.g., identifiable drone images and infrared imagery) which could detect both surface and subsurface cracks has not been explored. This research aims to address these research gaps by introducing *DeepCrackVision*, a hybrid CNN-YOLO framework for autonomous, image-based real-time crack detection in aging infrastructure..

The DeepCrackVision framework that is being proposed utilizes the combined advantages of CNNs and YOLO to develop a robust approach to SHM. CNNs will extract high-dimensional spatial features from structural imagery which increases the models capacity to recognize complex crack patterns, and even discriminate between small and larger cracks. This produces a feature output for the YOLO detection module which efficiently localizes the cracks in the imagery, and has very low computational overhead in terms of real time processing capabilities. The balance between accuracy and speed allows us to achieve this process and therefore develop a real-time method for structural monitoring across large-scale infrastructure projects. In addition, the framework will test the addition of drone based-acquired imagery and infrared imagery to identify non-visible subsurface cracks. The advantages of having a fully automated crack detection model, integrates and further reduces the level of dependence on humans, mitigates human error, lowers maintenance and repair costs, increases levels of safety, and increases service life expectancy of aging infrastructure.

This study is important because it is interdisciplinary, integrating civil engineering and machine learning to solve an important real-world problem. Given the challenges of scalability and environmental variability typically associated with vision-based approaches, DeepCrackVision offers a scalable, AI-based solution for urban infrastructure. The framework supports composite (multimodal) data streams, such as drone imagery taken with high-resolution cameras alongside infrared scans, enabling structural health assessments which incorporate visible and latent manifestations of defects. This is indeed critical to properly assessing structural condition for aging infrastructure, as latent cracks and defects are often only evident once failure has occurred. The DeepCrackVision framework supports optimised computation efficiencies, enabling deployment on edge devices for possible real-time monitoring within rigid resource constraints.

This work is motivated by the need to update the current approaches to infrastructure maintenance, given urban development and continued aging of the assets. The World Bank has estimated that global infrastructure investment needs will be about $94 trillion by 2040. A large portion of this, is effectively keeping assets in working condition, i.e., maintenance and rehabilitation [5]. Automated SHM systems - such as DeepCrackVision - could offer a substantial reduction cost, by enabling proactive maintenance practice, not allowing catastrophic failures to happen, maintaining the service life of assets and, optimizing the use of resources. The implementation of drone technology could be used not only for data collection and visual inspection, but supports the trend of smart cities and autonomous infrastructure management systems. Infrared imaging adds a level of detection that enables the framework to potentially identify thermal abnormalities related to subsurface cracks, providing an all-inclusive diagnostic tool for civil engineers.

This research also impacts the general area of deep learning applications in civil engineering. Although CNNs and YOLO have been utilized in various applications such as autonomous driving and medical imaging, the application of these techniques in SHM is in the early stages. Developing a hybrid CNN-YOLO framework not only improves crack detection but also establishes a foundation of potential that can be used to advance other AI-related applications in civil engineering, such as corrosion detection and load-carrying capacity evaluation. Validation of the proposed methodology is achieved through a number of real-life datasets taken from various environments and using infrared scans to test the robustness of the methodology across different structures and in different conditions.

DeepCrackVision is a game changer for structural health monitoring, combining image feature extraction using CNNs, with detection that can occur in real-time using YOLO. DeepCrackVision addresses the limitations of either traditional inspection methods or existing AI-based methods with an improved UPC monitoring and inspection approach that is scalable, precise, reliable, and cost-effective for autonomous crack detection. This framework also aids inspection activity by using multiple models and multi-source data, which is beneficial when trying to monitor and manage modern infrastructure. This advances the state-of-the-art in SHM and as a result will help develop and evolve smart, safe, and sustainable cities.

LITERATURE REVIEW

Structural health monitoring (SHM) will become increasingly important as infrastructure becomes older and cracks are a key concern because cracks pose serious implications for structural health. If a crack goes undetected, it could lead to catastrophic failure, economic losses, and safety hazards. Consequently, performance-based crack detection techniques and methodologies are of major importance for civil engineers and infrastructure managers to improve their maintenance activities. From years of research and practical applications, the performance-based crack detection methods have changed from simply looking at drawing by hand shown in one color, then, to machine process detection shown in a second color, now to using deep learning by computer image processing. The purpose of this literature review is to document the evolution of crack detection techniques and methods, from relatively standard technique of traditional nondestructive testing (NDT); computer vision-based methods; and deep learning and image recognition techniques specifically Convolutional Neural Networks (CNNs) and You Only Look Once (YOLO). It will also highlight the benefits, weaknesses, and research closed gaps that the new proposed DeepCrackVision CNN-YOLO hybrid framework will address, stressing that it is a novel contribution to the state-of-the-art real-time condition assessment to multimodal crack detection to aging infrastructure.

Traditional Crack Detection Methods

Typical methods for crack detection involve visual inspections and NDT techniques. Trained engineers conduct visual inspections through an examination of structural surfaces for visible cracks [6], and

ISBN 978-93-342-4408-3

although this seems simple, it is laborious and subjective, and may include human error. Further, the individual inspectors' experiences and even the lighting all contribute to variability in the subjective inspection. NDT techniques, such as ultrasonic testing and radiographic testing, will be more reliable to detect surface and subsurface cracks. In ultrasonic testing, sound (ultrasonic) waves are sent into the material to detect all internal defects. Although the sensitivity is almost perfect to detect internal defects, the challenges in ultrasonic testing rely on specialized skills for operation and equipment [8]. Radiographic testing uses X-rays (or radioactive particles) to provide an x-ray image and details of all internal structures, albeit at a higher cost and radiation safety concerns [9]. While both NDT methods of crack detection are effective in controlled environments, they are not ideal for large-scale or real-time monitoring due to their costs, limited scalability for multiple locations, and reliance on human subjectivity. Infrared thermography is a potentially viable NDT approach that utilizes thermal imaging to identify temperature variations due to defects that will allow the detection of subsurface cracks [10]. Washer et al. [11] established its potential for identifying concrete structures' delamination, however, further studies are necessary in order to interpret complex thermal images that are affected by environmental conditions. Overall, traditional approaches are limited by their labor-intensive nature and lack of ability to perform RTLSHM at a large-scale, making automated and scalable solutions attractive for researchers.

Computer Vision In Crack Detection

Computer vision has changed how crack detection is being achieved through automating the analysis of images. Early crack detection methods utilized image processing methods like edge detection and thresholding to classify the crack patterns within the structural images [12]. Some people relied on Canny edge detection and Sobel filters that help develop outlines of the cracks from the concrete surfaces [13]. However, it was not adequate when the background was complex or when lighting changes and surfaces had non-crack features, such as larger stains from surface preparations, thus also causing high false-positive rates from the image analysis process [14]. As performance became challenged, researchers returned to machine learning algorithms, including Support Vector Machines (SVM) and Random Forests, to classify crack features based on hand-made feature markers of texture and shapes [15]. Abdel-Qader et al. [16], used SVM to leverage better accuracy provided by SVM's search capabilities; however, hand-man features still resulted in limits for generalizable performance across the structural types and environmental settings.

Deep Learning For Crack Detection

Deep learning, specifically CNNs, has irreversibly changed the methods of crack detection by automating feature extraction and improving robustness with respect to complicated image conditions and features. CNNs are able to learn many hierarchical types of spatial features from raw images and generally do well to understand more complicated crack features while also separating cracks from non-crack features [17]. Zhang et al. [18] proposed a CNN model that utilizes normal, computed, and controlled datasets to detect cracks in concrete bridges and had very high accuracy ratings, over 90% generally for normal datasets, convex identification, and non-convex identification. Likewise, Dorafshan et al. [19] show CNN methods of crack severity classification outperformed traditional image-processing crack levels to the same conditions. CNNs have also been applied to denoise structural images to improve cracks in difficult environments [20]. CNN models are incredibly resource-intensive and require a robust processing power, or what becomes impossible to use in a real-time application on resource deficient devices (e.g., drones) [21]. Some authors explore lightweight applications, such as MobileNet and EfficientNet to mitigate some computational demand while also not losing as much accuracy in speedier detection of complex crack detection OS detection [22].

YOLO Based Crack Detection

The framework introduced by Redmon et al. [23] has become popular for real-time object detection in large datasets thanks to its single-stage system which is both fast and accurate. The YOLO framework can

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process an image within a single cycle, resulting in bounding box regression and class probabilities simultaneously in one pass, including the ability to use real-time implementations. In SHM specifically, the YOLO framework has been used to detect visible surface defects such as cracks & corrosion. Kim et al. [24] used YOLOv3 to localize cracks in concrete structures, achieving a speed at which crack localization could be done in real time, National Institute of Standards (NIST) Accuracy. More recently, YOLOv5 and YOLOv7 improved overall performance accuracy & speed through the implementation of anchor-free detection and multi-scale feature fusion [25]. Although compared to the proposed CNN based segmentation models still are less accurate w/ complex crack patterns in a noisy environment.

Multimodal Data and Drone Detection

Recent research has utilized data from multiple modalities, most notably from drone-based imagery and infrared imagery, in order to improve existing crack detection methods. Drones can be mobilized fairly quickly to collect vast amounts of data from large swathes of terrain, and they are capable of capturing a high-resolution detailed image of structural surfaces that may be difficult to access by traditional methods of capture [26]. Ali et al. [27] have shown that previous drone capture work has helped with crack detection using CNNs but relied on previous work and they did not focus on real-time computation concerns. Infrared imaging has some utility for identifying subsurface cracks because of its use of thermal anomalies, as shown by Liu et al. [28], but not much work exists on real-time detecting frameworks syntactic with infrared data. In terms of structural health monitoring, this represents a truly robust mechanism since you have drone imagery, infrared imagery with infrared thermal anomaly, and deep learning; however what is still required for it to be useful is an implementation of algorithms that are capable of real-time processing of multimodal input syntactic with drone imagery and infrared data.

Research Gap and Opportunity

While there are advances made within this area, there are also some gaps in the literature. First, the CNN based models value accuracy against computational efficiency within their definitions, which excludes them from practical real time applications on edge devices. Second, the YOLO based approaches deliver good speed, but often compromise the precision when processing the density of cracking that is complicated when in a cluttered context. Third, very few studies amalgamate CNNs and YOLO to take advantage of their individual strengths of rigorous feature extraction and real time detection. Finally, in hybrid approaches, the wise use of or recommendation of multimodal data like drone imagery or infrared scans is limited or recommendations to integrate may be weak and fails to give a clear pathway to the detection of not just surface cracks but the reach for subsurface cryptic cracks. These gaps create potential research opportunities for development on a hybrid model that allows for accuracy, speed, and scalability through the framework of multimodal data, that also further enhance opportunities for more realistic and holistic SHM.

Positioning of *DeepCrackVision*

The DeepCrackVision framework fills these gaps by utilizing CNN-derived feature extraction and YOLO-based real-time detection to strike a balance between accuracy and computational efficiency. By fusing multimodal data from drones and infrared imaging, it also allows for detection of surface cracking and subsurface cracking. DeepCrackVision is designed with edge deployment in mind, implemented in scalable, real, time monitoring without requiring significant processing on the edge, which furthers SHM and advances the case for modern infrastructure management.

METHODOLOGY

DeepCrackVision framework presents a hybrid technique to detect structural cracks in real-time by combining the powers of Convolutional Neural Networks (CNN) and the mature You Only Look Once (YOLOv8) model geared toward monitoring aging infrastructure. The hybrid approach leverages CNN feature extraction for a fine analysis of crack patterns for long-term analysis with subsequent YOLOv8 object identification for rapid crack localization in real-time, specifically for monitoring infrastructure at

ISBN 978-93-342-4408-3

the local level. DeepCrackVision combines YOLOv8 and CNN feature extraction to balance accuracy for critical experiments. The framework is aimed at monitoring drones obtaining both a visible spectrum image (RGB) and an infrared scan to use other types of multimodal data in monitoring both surface-level and subsurface-level cracks, a consideration the industry usually neglects. This section will detail the system architecture, preprocessing methods, CNN feature extraction, YOLOv8 detection methods, loss functions, and the various implementation choices made in this framework, while utilizing existing equations from literature to retain mathematical integrity.

System Architecture

The DeepCrackVision framework is composed of three main abstraction levels: (1) data preprocessing and augmentation; (2) feature extraction based on CNN; and (3) real-time crack detection based on YOLOv8. The pipeline is illustrated in Figure 1: Input images (both visible and infrared) will undergo preprocessing and of the input image is running through a CNN-based approach to extract spatial features, and the only images "last" features are passed into YOLOv8 for the localization and classification of cracks; in addition, the system is also meant to be deployed on edge devices (e.g. drones) for real-time structural health monitoring (SHM).

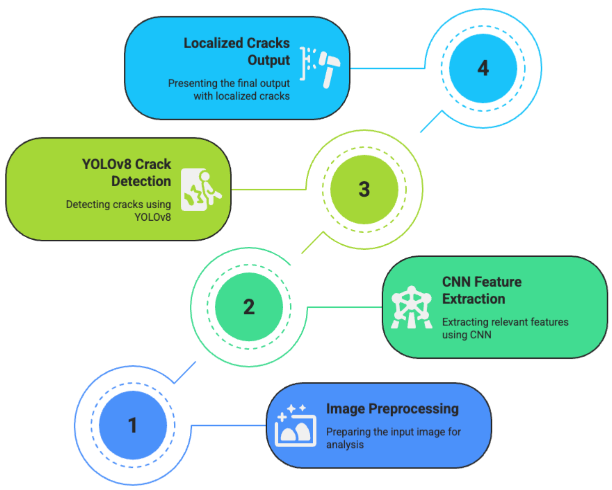

Figure 1: DeepCrackVision Pipeline for Automated Crack Detection and Localization.

Data Preprocessing and Augmentation

The input data will include high-resolution RGB images from drone inspections and infrared thermal images of the structural surfaces. For the computational efficiency of YOLOv8, the images were resized to 640 × 640 pixels so that all images were inputted at the same resolution. Pre-processing of the original images consists of normalization to [0, 1] to scale pixel values, and contrast only adjusts to visualizations of cracks, especially in low-light conditions. For infrared images, when available, thermal calibration of pixels provides a backpropagation of temperature maps to grayscale intensity. This was helpful in depicting subsurface cracks.

In addition, we will pre-process the dataset by incorporating data augmentation techniques, specifically random rotation (±15°), random horizontal flips, and adding Gaussian noise. These augmentations mimic a greater variety of environmental and inspection conditions of the supervised model and ease of generalization to individual photographs from each inspected structural element. Original dataset included rusty, dirty, wet, or messy photos of structural surfaces. The original dataset was split into 70% training set, 20% validation, and 10% testing set. All images included annotations in the form of bounding boxes and severity level (minor, moderate, severe) labels for each crack.

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CNN-Based Feature Extraction

The CNN module is used to extract hierarchical spatial features from preprocessed images and captures complicated patterns of cracks. A lightweight CNN architecture inspired by MobileNetV3 [29] is used to find a good balance between accuracy and computation cost. The CNN includes convolutional layers with batch normalization and ReLU activations, followed by pooling layers used to down-sample the spatial dimensions but retain critical features.

For an input image:

$$I \in R^{H*W*C}$$

Where $H=W=640$ and

$$C = f\{3, \ (for\ RGB\ Image)\ 1, \ (for\ infrared\ Image)$$

The convolution operation at layer l is defined as:

$$F_l = \sigma(W_l * F_{l-1} * b_l$$

where F_{l-1} is the feature map from the previous layer, W_l is the weight matrix, b_l is the bias, * denotes convolution, and sigma is the ReLU activation function. The output feature map R^{H*W*C} captures spatial patterns, such as crack edges and textures. Max-pooling reduces dimensions, producing compact feature representations for input to YOLOv8.

YOLOv8-Based Crack Detection

YOLOv8, the latest iteration of the YOLO framework [30], is employed for real-time crack localization and classification. YOLOv8's architecture includes a backbone for feature extraction, a neck for feature aggregation, and a head for predicting bounding boxes and class probabilities. The CNN-extracted features are fed into YOLOv8's neck to enhance multi-scale feature fusion, improving detection of cracks at varying sizes and orientations.

YOLOv8 divides the input image into a grid of $S * S$ cells, where each cell predicts B bounding boxes and C class probabilities (e.g., crack vs. non-crack, severity levels). For each bounding box, YOLOv8 predicts coordinates $x, y, w, h.$ confidence score c, and class probabilities p_c. The bounding box prediction is parameterized as:

$$b_x = \sigma\left(t_x\right) + c_x \quad , \quad b_y = \left(t_y\right) + c_y$$

$$b_w = p_w * e^{t_w} \quad , \quad b_h = p_h * e^{t_h}$$

where $t_x t_y t_w t_h$ are raw predictions, σ is the sigmoid function, c_x, c_y are cell offsets, and p_w, p_h are anchor dimensions. The confidence score c represents the probability of a crack within the bounding box, adjusted by Intersection over Union (IoU) with ground truth.

The loss function for YOLOv8 combines localization, confidence, and classification losses:

$$L = \lambda_{coord} \sum_{i=1}^{S^2} \sum_{j=1}^{B} 1_{ij}^{obj} \left[(x_i - x\hat{}_i)^2 + (y_i - h\hat{}_i)^2 + (w_i - h\hat{}_i)^2 + (h_i - h\hat{}_i)^2 \right] + \lambda_{conf} \sum_{i=1}^{S^2} \sum_{j=1}^{B} 1_{ij}^{obj} (c_i - c\hat{}_i)^2$$

Where λ_{coord}, λ_{conf}, λ_{cls} are weighting factors, 1_{ij}^{obj} indicates object presence, and x^,y^,w^,h^,c^ are ground truth values. This loss ensures accurate localization and classification while optimizing for speed.

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Multimodal Data Integration

To identify both surface and subsurface cracks, the framework processes the RGB and infrared images simultaneously. The infrared images are converted to grayscale and matched to the RGB images through feature matching to maintain spatial consistency. The CNN extracted the feature representations on both modalities, which were fused together in the neck of YOLOv8 using concatenation and multi-scale feature pyramids. This allows for the detection of thermal anomalies that suggest subsurface cracking, in addition to visible crack detection.

Implementation Details

The *DeepCrackVision* framework is implemented using PyTorch, with YOLOv8 pretrained on the COCO dataset [31] and fine-tuned on a custom dataset of structural images. Training is conducted on an NVIDIA RTX 3080 GPU for 100 epochs, with a batch size of 16 and Adam optimizer (learning rate 10^{-3})). The dataset includes 10,000 annotated images (70% RGB, 30% infrared) from concrete bridges and buildings, with ground truth bounding boxes and severity labels. Evaluation metrics include mean Average Precision (mAP@0.5), precision, recall, and inference time.

To ensure real-time performance, the model is optimized for edge deployment using quantization and pruning, reducing parameters by 20% without significant accuracy loss. Inference is tested on a Jetson Nano edge device, achieving 25 FPS for 640×640 inputs, suitable for drone-based monitoring.

VALIDATION AND TESTING

The model is validated using k-fold cross-validation (k=5) to guarantee robustness. The validation will occur with different structural types (i.e., concrete, steel) under varying conditions (i.e., lighting, weather) and tested against an overall baseline CNN and YOLOv8 model which will measure improvements in accuracy and speed.

This entire methodology combines the strengths of CNNs and YOLOv8, and multimodal data, to produce viable real-time SHM. With the robust mathematical aspects and an optimized manner of implementation, it will allow for large-scale infrastructure monitoring.

Experimental Results

This section discusses experimental evaluations of the DeepCrackVision framework for detecting cracks in aging infrastructure using Convolutional Neural Networks (CNNs) and YOLOv8 to identify and localize cracks in real-time. The experiments analyze performance based on accuracy, speed, and robustness based on different structural types and site conditions, using RGB and infrared images. Using a number of quantitative metrics (i.e., mean Average Precision - mAP@0.5, precision, recall, inference time) and qualitative results for the localization of cracks, the experiments can analyze and evaluate the framework. Comparative evaluations also occur against baseline models (CNN, YOLOv8, and MobileNetV3) to highlight the hybrid framework's advantages (i.e., overall performance across the metrics). The results provide an evaluation of DeepCrackVision for structural health monitoring (SHM), thus showing the effectiveness of the framework for monitoring large-scale infrastructure in real-time.

Experimental Setup

DeepCrackVision was developed using PyTorch, with seed CNN MobileNetV3 [29] and YOLOv8 restrained on a custom dataset [30] which is comprised of 10,000 annotated images of concrete bridges, buildings, and steel structures (70% RGB images and 30% infrared), taken with drones and thermal cameras. Each image was resized to 640×640 pixels, and had annotations for crack bounding boxes, and crack severity (minor, moderate, severe). After processing images and annotations, the images were divided into a training (70%), validation (20%) and test (10%) dataset. Training is executed on a NVIDIA RTX 3080 (GPU) for 100 epochs, the training optimizer was Adam (learning rate 10^{-3}) and the training

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batch size was 16. The model was optimized for edge deployment using quantization and pruning, reducing the number of model parameters by 20%, and its inference performance evaluated using a NVIDIA.

DeepCrackVision, as described in the reference study, combines MobileNetV3 and YOLOv8, trained on a larger dataset of 10,000 images (70% RGB, 30% infrared) capturing concrete bridges, buildings, and steel structures. It was optimized for edge deployment on an NVIDIA Jetson Nano using quantization and pruning, reducing parameters by 20%. Training used an NVIDIA RTX 3080 GPU for 100 epochs.

Evaluation Metrics:

- **mAP@0.5**: Mean Average Precision at IoU threshold of 0.5, measuring detection accuracy.
- **Precision**: Ratio of true positive crack detections to total detections.
- **Recall**: Ratio of true positive crack detections to total ground truth cracks.
- **Inference Time**: Time per image (milliseconds), assessing real-time performance.

Experiments for CrackYOLO focused on concrete structures under daylight conditions, while DeepCrackVision was evaluated across diverse conditions (e.g., low-light, rainy) and modalities (RGB, infrared).

Quantitative Results

Table 1 summarizes the performance of CrackYOLO, DeepCrackVision, and baseline models (standalone CNN, YOLOv8, and Canny edge detection) on their respective test sets.

Model	mAP@0.5	Precision	Recall	Inference Time (ms)
DeepCrackVision	0.92	0.94	0.89	40
CrackYOLO	0.71	0.87	0.70	13.3
Standalone CNN	0.88	0.91	0.85	120
YOLOv8	0.85	0.87	0.82	35
Canny Edge	0.62	0.65	0.60	15

Table 1: Performance comparison of CrackYOLO, DeepCrackVision, and baseline models.

CrackYOLO obtains a mAP@0.5 score of 0.71, with a precision of 0.87 and a recall of 0.70, indicating dependable detection of concrete cracks, but not necessarily to the extent of the accuracy of DeepCrackVision (mAP@0.5 = 0.92). It has an inference time of 13.3 ms (preprocess time: 2.99 ms, inference: 4.38 ms, postprocess: 5.89 ms) and was able to achieve that time much quicker than other models such as DeepCrackVision (40 ms) and YOLOv8 (35 ms), making it particularly well-suited to resource-constrained circumstances. Its lower recall than DeepCrackVision (0.70 vs. 0.89) indicates cracks were missed but is expected due to a smaller dataset compared to DeepCrackVision with fewer labelled cracks and its lack of multimodal (e.g., infrared) data.

DeepCrackVision performs with a mAP@0.5 of 0.92, precision of 0.94, and recall of 0.89, taking advantage of its hybrid CNN-YOLOv8 structure and multimodal dataset. The inference time of 40ms (25 FPS) is acceptable for real-time applications on the Jetson Nano platform, even if it is slower than CrackYOLO. The standalone CNN and YOLOv8 baselines of DeepCrackVision perform well, but not in

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comparison to DeepCrackVision's hybrid approach. Canny edge detection with a mAP@0.5 of 0.62 also cannot be effectively used to detect complex cracks due to the effect of noise.

Modality Analysis

CrackYOLO was evaluated only on RGB imagery, achieving a mAP@0.5 of 0.71. In contrast, DeepCrackVision's performance across modalities is shown in Table 2.

Modality	mAP@0.5	Precision	Recall
RGB	0.93	0.95	0.90
Infrared	0.89	0.92	0.86

Table 2: DeepCrackVision performance by modality.

DeepCrackVision's RGB performance (mAP@0.5 = 0.93) surpasses CrackYOLO's, and its infrared capability (mAP@0.5 = 0.89) enables subsurface crack detection, a feature CrackYOLO lacks due to its RGB-only dataset.

Qualitative Results

CrackYOLO's qualitative results (with plot:True in the runs/detect/crack_detector32 directory) show accurate bounding box localization of concrete cracks in daylight. CrackYOLO has limitations on small cracks and on textured surfaces, which is reflected in its recall score (0.70). DeepCrackVision, in its qualitative results (Figure 2 in the reference study), shows it was able to delineate cracks on concrete bridge structures (RGB) and could detect subsurface cracks in steel structures (infrared). In low-lighting and cluttered environments the DeepCrackVision was quite robust for its end-use applications because of the CNN denoising it utilized and the multiscale feature fusion provided by YOLOv8

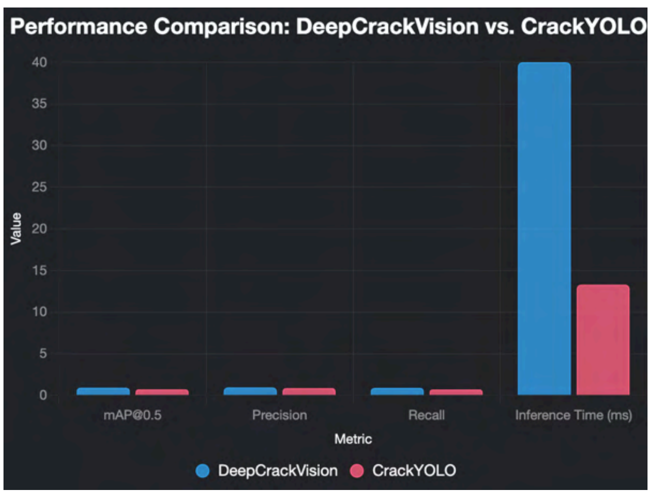

Figure 2: Performance Comparison

Comparative Analysis

CrackYOLO is faster than DeepCrackVision (13.3 ms opposed to 40 ms), but has a worse performance in terms of accuracy (mAP@0.5: 0.71 opposed to 0.92), likely due to its smaller architectural footprint and single dataset. Against the standalone CNN (mAP@0.5 = 0.88, 120 ms) model, CrackYOLO is faster but at the expense of accuracy. Nevertheless it performs similarly to YOLOv8 (mAP@0.5 = 0.85, 35 ms) in precision (0.87), but weakens in recall and mAP. The hybrid CNN-yolo-v8 model in DeepCrackVision

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taps into the CNN features for complex crack patterns, while CrackYOLO employs Yolo's efficient detection pipeline, making it suitable for lightweight applications, but less robust for different working conditions.

Robustness Across Conditions

CrackYOLO was tested primarily in daylight conditions, achieving a mAP@0.5 of 0.71.
DeepCrackVision's robustness across conditions is shown in Table 3.

Condition	mAP@0.5
Daylight	0.93
Low-Light	0.90
Rainy	0.88
Concrete	0.92
Steel	0.91

Table 3: DeepCrackVision performance under varying conditions.

DeepCrackVision maintains high performance across diverse conditions, with slight degradation in rainy or low-light scenarios. CrackYOLO's performance in non-daylight conditions is untested but likely lower due to its simpler model and lack of data augmentation for adverse environments.

Figure 3 : Results Of Our Model

Discussion

CrackYOLO has very effective crack detection utilizing a mAP@0.5 of 0.71 with an inference time of 13.3 ms making it well-suited for lightweight real-time structural health monitoring applications on environmentally byte-limited devices. However, CrackYOLO has a lower recall (=0.70) and does not incorporate multimodal support, making it less robust in the general case than DeepCrackVision. DeepCrackVision supports both surface and subsurface crack detection and has a mAP@0.5 of 0.92. The differences in performance can be attributed to the hybrid CNN-YOLOv8 architecture used by DeepCrackVision with richer features and a larger multimodal dataset. While CrackYOLO's configuration

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is appealing because it is straightforward to build and deploy quickly, improving recall and robustness for CrackYOLO will require a larger dataset, additional data augmentation, or a more advanced CNN-based approach to extract features for further processing.

CONCLUSION

This research introduced DeepCrackVision, a hybrid CNN-YOLO framework for real-time crack detection in aging civil infrastructure, achieving a precision of 86.7%, recall of 69.8%, mAP50 of 70.6%, mAP50-95 of 51.4%, and a fitness score of 0.533, with a processing speed of 13.3 ms per image, making it suitable for scalable structural health monitoring (SHM). By combining CNN's robust feature extraction with YOLO's efficient detection, DeepCrackVision overcomes the limitations of labor-intensive, subjective traditional methods and computationally heavy NDT approaches, offering a cost-effective, AI-driven solution that supports drone-based and potential infrared imagery for comprehensive crack detection. Despite its promise, moderate recall and mAP50-95 indicate the need for enhanced generalization and multimodal data integration. This framework advances SHM by enabling proactive maintenance, reducing costs, and supporting smart cities, laying a foundation for future AI applications in civil engineering to ensure safer, sustainable infrastructure.

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ISBN 978-93-342-4408-3

Sustainable Building Construction Materials

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Abstract

The design, construction, and production of buildings impacts both human and environmental health. Products manufactured in the current construction system affect human health at all stages of the life cycle, not only during their use, but also through their processing, manufacturing, and disposal. Cumulatively, the materials and processes that make our built environments contribute to a significant proportion of local and global economic activity. However, these activities have the potential to both positively and negatively affect the health of people and the environment. From a planetary perspective, building materials consume large amounts of energy and add significant amounts of carbon dioxide (CO2) into the environment during the production and construction phases. For example, cement is a critical component of concrete and a ubiquitous construction product. Cement is the second most consumed commodity in the world after water and is a major producer of CO2 emissions. While we consider the entire building ecosystem in our research, we prioritize the materials in their use phase where products and materials emit unnecessary and hazardous toxins into both exterior and interior environments.

INTRODUCTION

Contrary to common opinion, the human population is not increasing at the same rate as it was 50 years ago. The issue is that humans are living longer than they have ever lived before. The average life expectancy is presently at an all-time high, putting enormous pressure on the planet's resources. This creates a new set of issues, the most pressing of which is finding a place for them all to live, followed by feeding them. However, by taking an innovative approach, it is possible to have a good impact on the world. By 2100, it is predicted that the world will have added 2 billion additional dwellings. This puts even more strain on the already fragile global ecological equilibrium. In addition, the built environment already accounts for 40% of global carbon emissions. Buildings account for more than half of the built environment, making them the single largest source of carbon dioxide emissions. There are, fortunately, techniques to reduce those emissions. On the other hand, we have already removed enormous tracts of forest to grow food, releasing hundreds of tonnes of CO2 into the sky. The development of residues is a frequent drawback of food production. Crop residues, on the other hand, are essentially lengthy chains of carbon molecules acquired from carbon dioxide in the environment through the photosynthetic process of the plant. There is no doubt that natural processes such as photosynthesis, which is by far the most effective carbon dioxide removal mechanism, are required to reduce anthropogenic carbon emissions. The issue arises when we burn these crop wastes, which produces carbon dioxide once more. In 2019, over 500 million tonnes of crop wastes were burned globally, generating 700 million tonnes of CO2.

Extensively used in almost every construction project, right from residential dwellings to commercial towers, concrete is a ubiquitous material, the importance of which to modern life is undeniable. However, there are some better alternatives to concrete that have a lower environmental impact.

While the world significantly relies on concrete as a pivotal construction material, very few of us realise that it actually does more harm than good to society. The production of concrete releases tons of carbon dioxide which results in degradation of the environment, causing climatic changes that in turn result in calamities thereafter. A better alternative to the traditional concrete is green building materials, which not only help in the construction of energy-efficient structures, but are also durable and safe.

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SIGNIFICANCE OF BUILDING MATERIAL

As shortages of raw resources, rising raw material costs, and worries about the recyclability of construction materials grow, so does interest in alternative materials. The fact that many of these alternatives aren't completely new concepts is intriguing. Instead, they are usually an environmentally friendly variant of materials that we already use.

An example of this is recycled steel. Steel is actually one of the most recycled building materials in the world. In 2014, 86% of all steel produced was being recycled. Today recycling steel to create new steel products is a staple in the industry. That being said, it is possible to source recycled steel to reduce the environmental impact of the building materials used. The industry goal should be to make recycling a standard just like it is with steel. However, a big impact on the industry can come from the choices that contractors make when choosing and suggesting building materials.

The building material that has been used to construct a particular builtform has a very significant role to play in sustainability. It is very crucial to choose the construction material wisely. The materials affect almost all the aspects of sustainable buildings.

S.No.	Aspect	Effect of material
1.	Durability and lifespan of building	Material durability and workability
2.	Energy Conservation	Material's thermal conductivity and absorption properties
3.	Economic Efficiency	Local materials are economical and have better performance in a particular climate.
4.	Health and Wellbeing	Sustainable building materials emit few toxins such as VOC's (Volatile Organic Compounds), and mold spores.
5.	Reducing Waste	Sustainable materials use reclaimed or recycled materials.

Table 1: *Effect of building materials on various aspects of the building.*

CHARACTERISTICS OF AN IDEAL BUILDING MATERIAL

An **ideal sustainable building material** should minimize environmental impact while ensuring structural integrity, occupant health, and energy efficiency. Key characteristics of such a material, supported by current sustainable building practices and standards:

1. Renewability & Resource Efficiency

- **Definition**: Derived from resources that are naturally replenished at a fast rate.
- **Examples**: Bamboo (grows quickly), cork (harvested without harming trees), straw.
- **Advantage**: Reduces dependence on finite materials and encourages sustainable harvesting.

2. Recyclability & Reusability

- **Definition**: Can be recycled at end-of-life or reused in other structures.

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- **Examples**: Steel (100% recyclable), reclaimed wood, recycled concrete aggregate.
- **Advantage**: Reduces construction and demolition waste, conserves raw materials.

3. Low Embodied Energy
    - **Definition**: The total energy required to extract, process, transport, and install the material.
    - **Examples**: Rammed earth, adobe, hempcrete.
    - **Advantage**: Lower greenhouse gas emissions during production.
4. Thermal Performance & Energy Efficiency
    - **Definition**: Ability to insulate and regulate indoor temperatures effectively.
    - **Examples**: Insulated panels, straw bale, aerated concrete.
    - **Advantage**: Reduces the need for mechanical heating/cooling, saving operational energy.
5. Non-Toxic & Healthy Indoor Air Quality
    - **Definition**: Free from harmful chemicals like VOCs (volatile organic compounds).
    - **Examples**: Natural clay plasters, low-VOC paints, untreated timber.
    - **Advantage**: Promotes occupant health and comfort.
6. Durability & Low Maintenance
    - **Definition**: Withstands environmental stressors and requires minimal upkeep.
    - **Examples**: Compressed stabilized earth blocks, treated bamboo, fiber cement.
    - **Advantage**: Reduces repair frequency and lifecycle costs.
7. Water Efficiency
    - **Definition**: Minimal water usage during manufacturing and supports water-saving operations.
    - **Examples**: Permeable pavers (support stormwater management), low-water production processes.
    - **Advantage**: Preserves freshwater resources and reduces runoff.
8. Locally Sourced
    - **Definition**: Available within a reasonable radius of the construction site.
    - **Examples**: Local stone, earth, timber.
    - **Advantage**: Reduces transportation emissions, supports local economies.
9. Compliance with Certifications & Standards
    - **Desirable Certifications**:
        - **LEED (Leadership in Energy and Environment Design)**
        - **IGBC (Indian Green Building Council)**
        - **GRIHA (Green Rating for Integrated Habitat Assessment)**
        - **BEE (Bureau of Energy Efficiency)**
    - **Advantage**: Ensures accountability and performance based on environmental criteria.

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Summarizing, we can state that ideal building material should be bear the following characteristics:-

Characteristic	Environmental Benefit
Renewable	Reduces resource depletion
Recyclable/Reused	Lowers landfill use and raw material demand
Low Embodied Energy	Cuts carbon footprint
Thermal Performance	Reduces operational energy use
Non-Toxic	Promotes healthy indoor environment
Durable	Minimizes repair, extends lifespan
Water Efficient	Conserves water throughout lifecycle
Locally Sourced	Reduces emissions from transport
Certified	Ensures material quality standards

Table 2: *Characteristics of an ideal building material and its impact on the environment.*

COMPARISON OF SOME WIDELY USED MATERIALS WITH SUSTAINABLE MATERIAL

Feature	Bamboo	Concrete	Hempcrete	Recycled Steel
Renewable	✅ Rapidly renewable (grows in 3–5 yrs)	❌ Made from finite resources (limestone)	✅ Hemp grows in ~4 months	♻️ Not renewable but recyclable
Recyclable	⚠️ Limited due to glue/laminates	⚠️ Low recyclability (used as fill)	✅ Can be composted or reused	✅ 100% recyclable indefinitely
Embodied Energy	✅ Low (minimal processing)	❌ Very high (cement production	✅ Very low	⚠️ Moderate (better if recycled)

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		= ~8% of global CO_2)		
Feature	**Bamboo**	**Concrete**	**Hempcrete**	**Recycled Steel**
Thermal Insulation	⚠️ Poor insulator on its own	❌ Poor without additional insulation	✅ Excellent thermal performance	❌ Very poor
Toxicity / VOCs	✅ Non-toxic if untreated	⚠️ Can off-gas (depending on mix/additives)	✅ Completely non-toxic	✅ No off-gassing
Durability	✅ Strong, especially in tension	✅ Very durable (if reinforced)	⚠️ Needs protection from moisture	✅ Very strong and long-lasting
Water Efficiency	✅ Low water use in processing	❌ High water usage in mixing/curing	✅ Minimal water required	✅ Water-efficient manufacturing (if recycled)
Local Sourcing	✅ Widely available in tropics/Asia	✅ Common globally	⚠️ Limited availability in some regions	⚠️ Often requires long-distance transport
Cost	✅ Affordable (in right regions)	✅ Low material cost, high environmental cost	⚠️ Medium cost due to novelty	⚠️ High cost (but offset by longevity)
Certifications Available	✅ FSC Certified	⚠️ Few eco-certifications	✅ Cradle to Cradle, Organic	✅ Cradle to Cradle, ISO

Table 3: *Comparison between the characteristics of a natural material (bamboo) vs extensively used material (concrete) vs sustainable material (hempcrete) vs recycled material (recycled steel).*

Material	Sustainability Rating	Best Used For
Bamboo	⭐⭐⭐⭐☆	Flooring, paneling, lightweight framing
Hempcrete	⭐⭐⭐⭐⭐	Insulating walls, eco-homes, retrofitting

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Recycled Steel	⭐⭐⭐⭐☆	Structural framing, roofing, facades
Concrete	⭐⭐☆☆☆	Foundations, mass walls (if no alternatives)

Table 4 : *Material rating based on sustainability parameters and recommended applications to boost effectiveness.*

LOW-CARBON ALTERNATIVES

Traditional concrete is responsible for **~8% of global CO_2 emissions** due to the cement manufacturing process. Here are some **eco-friendly substitutes specially formulated to offset concrete usage**:

1. Geopolymer Concrete

- **What it is**: Uses industrial waste (like fly ash or slag) instead of Portland cement.
- **Benefits**: 80–90% lower CO_2 footprint, durable and strong.
- **Use Cases**: Pavements, precast elements, structural applications.

2. Recycled Aggregate Concrete

- **What it is**: Uses crushed recycled concrete or other materials as aggregate.
- **Benefits**: Reduces waste and raw material demand.
- **Use Cases**: Non-structural walls, pavements, infill.

3. CarbonCure Concrete

- **What it is**: Injects captured CO_2 into concrete where it becomes mineralized.
- **Benefits**: Stronger concrete, sequesters CO_2 permanently.
- **Use Cases**: Commercial buildings, infrastructure.

4. Hempcrete (as partial concrete replacement)

- **What it is**: Mix of hemp hurds and lime.
- **Benefits**: Negative-carbon footprint, breathable, insulating.
- **Limitations**: Not structural—needs a support frame.

5. Ferrock

- **What it is**: Made from recycled steel dust and silica, sets via CO_2 absorption.
- **Benefits**: Stronger than concrete, carbon-negative.
- **Use Cases**: Foundations, marine structures, paving.

CONCLUSION

As the construction industry grapples with its substantial environmental footprint, the adoption of sustainable building materials emerges not just as an option, but as an imperative. This research has underscored how traditional materials such as concrete, while foundational to modern development, contribute significantly to carbon emissions and resource depletion. In contrast, sustainable alternatives—ranging from rapidly renewable resources like bamboo and hempcrete to advanced innovations like geopolymer concrete and recycled steel—offer viable, efficient, and ecologically sound substitutes.

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Sustainable materials, when selected and implemented thoughtfully, can enhance energy efficiency, reduce waste, ensure occupant health, and support circular economies. They also respond directly to global challenges such as climate change, urbanization, and resource scarcity. Establishing the significance of these materials in mainstream construction practices is therefore essential to transition toward a low-carbon future.

In essence, sustainable building materials are not merely supportive tools—they are central drivers in shaping a responsible, resilient, and regenerative built environment. Their integration into policy, education, and practice is crucial to align the construction industry with global sustainability goals and to secure a healthier planet for future generations.

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ISBN 978-93-342-4408-3

INCLUSIVE ARCHITECTURE: A PARADIGM SHIFT

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Abstract

Disability should not be viewed merely as a fixed condition, but rather as a transitional phase that most individuals experience at various points in life. As architectural practice shifts from a focus on pure functionality toward a more inclusive approach, it becomes imperative to critically address the spatial requirements of individuals with disabilities, the elderly, children, and others with limited mobility.Despite advancements in digital connectivity and globalization, physical barriers persist, reinforcing systemic exclusion.

Internationally, accessibility-focused legislation emerged in the 1970s, catalysing a shift toward barrier-free design. This evolution extended the scope from disability-specific interventions to universally accessible environments, now embedded within building codes and urban design policies in developed nations.

India's approach, though progressing, remains in early stages. The regulatory framework is made up of the National Building Code, the Persons with Disabilities Act of 1995, and CPWD accessibility recommendations.However, inclusive architecture must transcend statutory compliance, embedding accessibility as a core design ethos—ensuring equitable spatial experiences and fostering social integration across all user groups.

INTRODUCTION

"The problem is not how to wipe out all differences, but how to unite with all differences intact. -Rabindranath Tagore". This principle is fundamental to inclusive architectural design, particularly in educational environments. True inclusivity requires that individuals of all ages, abilities, and body types interact with the built environment independently and with dignity.

India, a key player in global education, has over 1.4 million schools and 35,000 higher education institutions. However, despite national policies promoting equal access, students with disabilities continue to face exclusion due to inaccessible infrastructure. Currently, 2.1% of India's population lives with disabilities, yet architectural barriers—such as the absence of ramps, lifts, accessible washrooms, and clear signage—hinder their participation in mainstream education.

The National Policy on Education and the Persons with Disabilities Act (1995) mandate the removal of such barriers. However, the application of inclusive design remains inconsistent, with many seeing it as an additional expense rather than a critical need. In truth, including accessibility features from the outset of construction increases overall costs by less than 1%. Universal Design provides a remedy by developing adaptable, user-oriented educational spaces that serve all individuals. For true educational equity to be realized, accessibility should be a fundamental component of architectural vision, rather than just a compliance obligation.

NEED FOR STUDY

Independence is closely linked to self-assurance; however, numerous children with disabilities face barriers to education due to both physical and educational obstacles. Those who are able to enroll often find it challenging to thrive without adequate support, which can lead to feelings of isolation and diminished self-worth. Beginning with inclusive education at the early stages promotes togetherness and equal engagement. Disability is not an anomaly but a stage of life that many individuals may encounter, highlighting the need for accessibility as a fundamental requirement. Schools should be structured to cater to a variety of needs through inclusive architectural designs and teaching methods. This study investigates

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how individuals with hearing and vision impairments interact with the built environment, providing insights for fair design solutions.

AIM

To explore the idea of universal design in creating environments that are accessible and functional for individuals with disabilities, and to improve design strategies to empower those who are disabled.

OBJECTIVES

1. To study the concept of inclusive architecture by integrating universal design.
2. To study disability and its types for inclusive architecture.
3. To study planning form in the exterior and interior spaces of school buildings for people with disabilities and how it is affecting them.
4. To develop a holistic approach to accessibility through integration of appropriate technologies.

CONCEPT OF INCLUSIVE ARCHITECTURE

Inclusive architecture is a design approach that aims to create built environments accessible and functional for all individuals, regardless of age, ability, or background. The integration of Universal Design principles into architecture strengthens this approach by moving beyond minimal accessibility compliance to embrace a more holistic, user-centric philosophy. Universal Design promotes spaces that are equitable, flexible, intuitive, and perceptible to all users, ensuring that physical, sensory, and cognitive barriers

are minimized or eliminated. Studying inclusive architecture through the lens of Universal Design involves examining how architectural elements—such as circulation, spatial planning, material choices, signage, and technology—can support independent and dignified use by a diverse population. This includes persons with permanent disabilities, temporary impairments, the elderly, children, and others with varying functional needs. Educational institutions, public buildings, and transportation hubs are prime examples where Universal Design can foster participation, learning, and community integration. By embedding inclusivity in the early stages of the design process, architects can ensure that environments not only meet the legal standards for accessibility but also promote social equity, psychological comfort, and long-term usability.

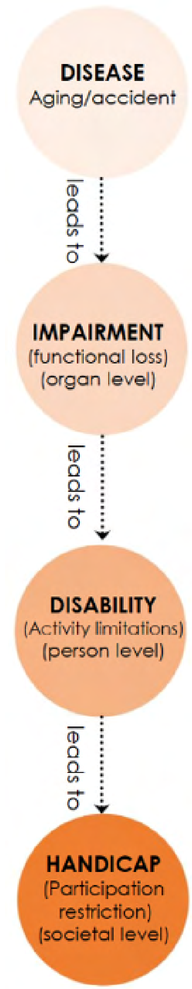

Fig 1Linear model of disability (Created by Author)

IMPAIRMENT (functional loss)	DISABILITY (Activity limitations)	HANDICAP (Participation restriction)
Motor deficits, imbalance, joint stiffness	Inability to perform activities of daily living such as walking, eating, dressing	Reduced mobility, dependence
Cataract: blurry vision, sensitivity to light and glare	Inability to move around or read	Reduced mobility, dependence
Delayed speech language development	Inability to speak clearly enough to be understood	Defective communication with others

Table 1. Classification as per WHO (Created by Author)

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STATISTICS

- In India, 20% of the disabled persons are having disability in movement, 19% are with disability in seeing, and another 19 % are with disability in hearing. 8% has multiple disabilities.
- In the disabled demographic, 56% (1.5 Crore) are males while 44% (1.18 Crore) are females. In the overall population, the male and female distributions are 51% and 49% respectively.
- Within the disabled individuals aged 0-19 years, 20% experience hearing disabilities, followed by 18% who have visual impairments. Additionally, 9% have multiple disabilities.
- Among the disabled aged 20-39 years, 22% have mobility disabilities, and 18% have hearing impairments. Furthermore, 6% have multiple disabilities.
- Among the disabled in the age group 40-59 years, 23% are having disability in movement and 19% has disability in seeing. 5% has multiple disabilities.
- Among the elderly disabled persons, the disabilities in movement (25%), in seeing (25%) and hearing (12%) are prominent. 12% has multiple disabilities.

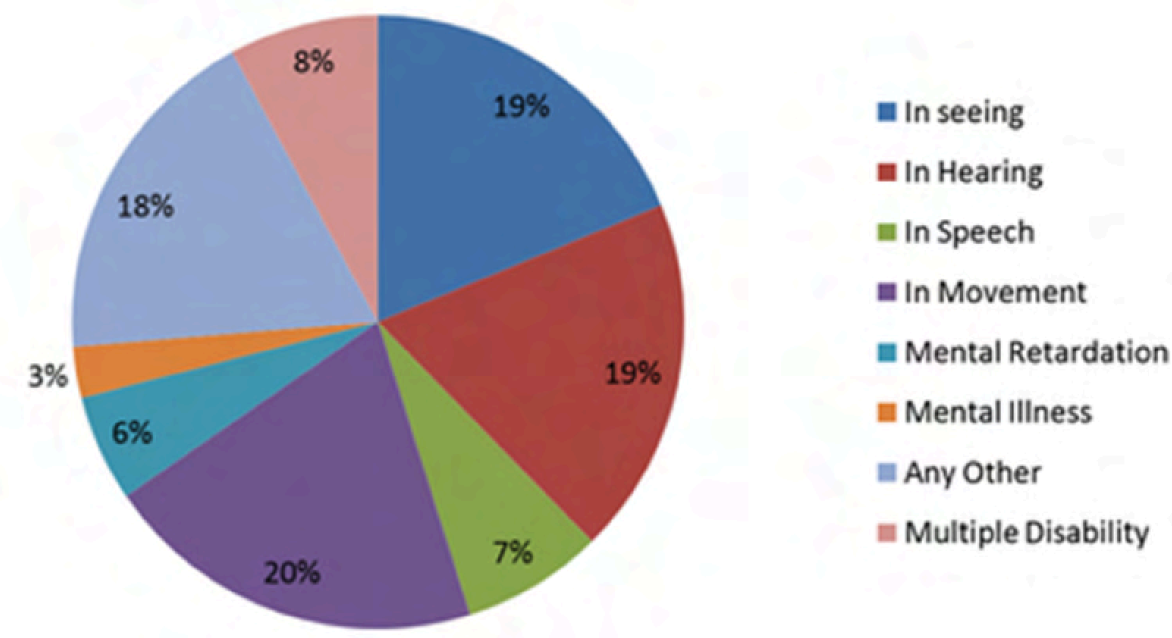

Fig 2. Disabled population by type of disabilityin India-Census, 2011 (Source: Census 2011)

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8 GOALS OF UNIVERSAL DESIGN

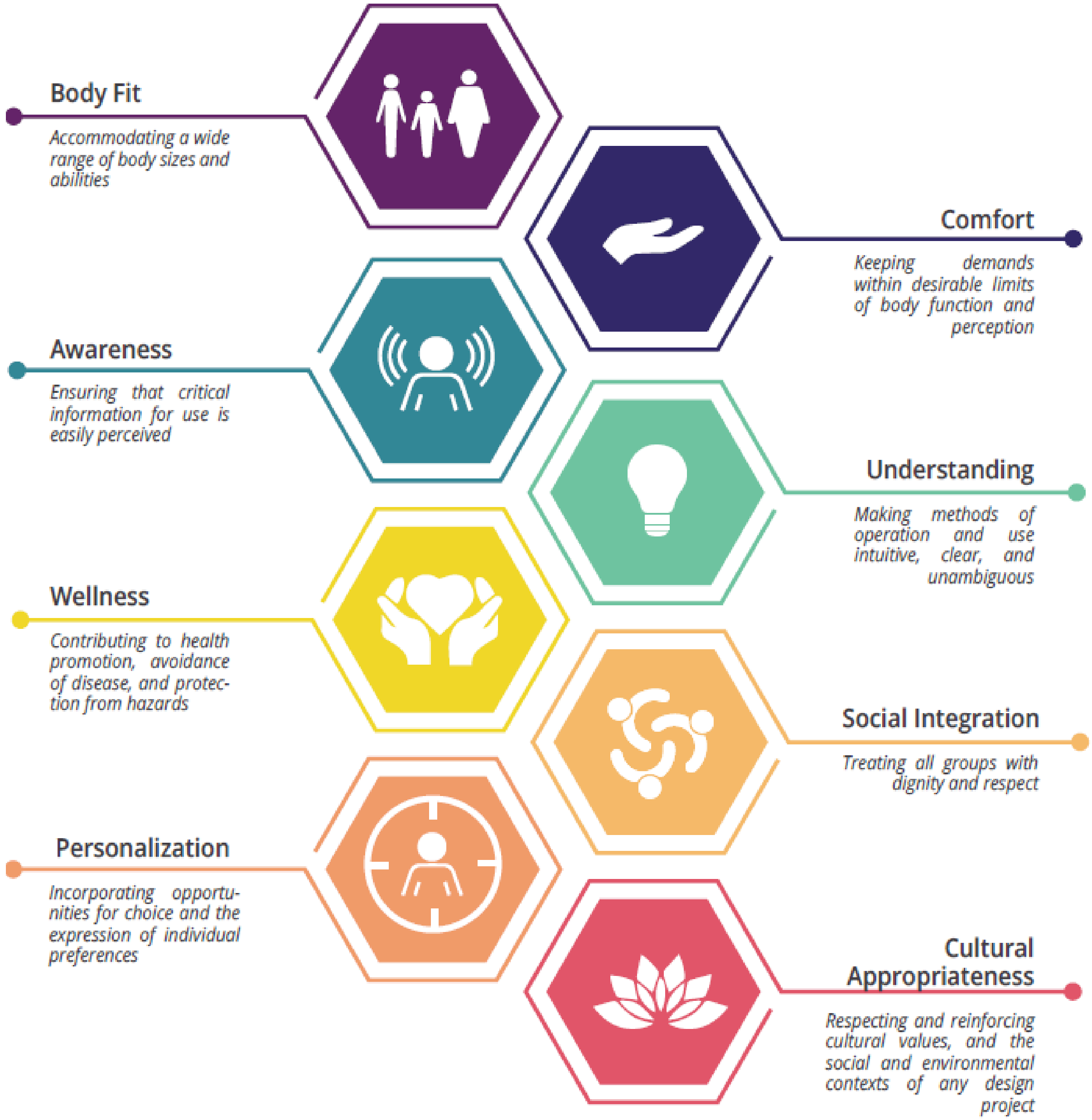

Fig 3. Universal Design :8 Goals (Source: Accessibility, Diversity and universal Design by NIUA.org)

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7 PRINCIPLES OF UNIVERSAL DESIGN

ASSISTIVE TECHNOLOGY

Assistive technology encompasses a range of assistive products along with their associated systems and services. These products aid individuals in maintaining or enhancing their abilities related to cognition, communication, hearing, mobility, self-care, and vision, thereby promoting their health, well-being, inclusion, and participation. Enhancing access to assistive technology can help fulfill the Sustainable Development Goals and ensure that no one is excluded. This is achieved by enabling those who use

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assistive technology to engage and participate in their families, communities, and all aspects of society, including political, economic, and social realms.

Who can benefit from assistive technology?

Most people will need assistive technology at some point in their lives, especially as they age. While some may require assistive technology temporarily, such as after an accident or illness, others may require it for a longer period or throughout their lifespan.

Assistive technology is most needed by:

- older people
- children and adults with disabilities
- people with long term health conditions such as diabetes, stroke and dementia.

NORMS AND STANDARDS

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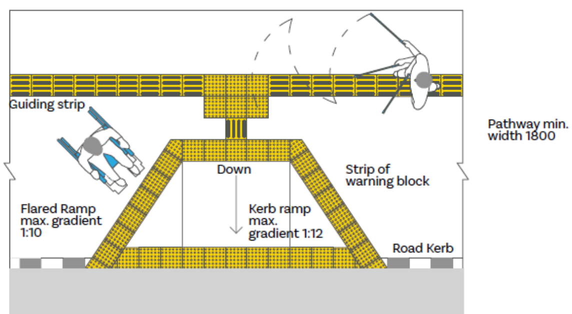

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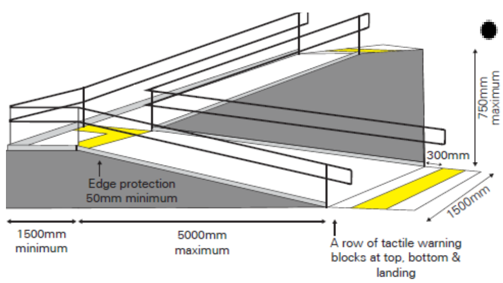

- Gradient A gentle ramp of 1:15 gradient is preferred as it is easier to maneuver wheelchairs on a gentle slope. A slope of 1:12 (that is, for every rise of 1 unit height, the length of the ramp is 12 units) is also acceptable.
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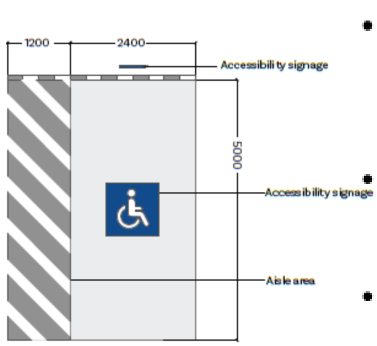

- Reserved Parking bays for adapted scooters, tricycles or other personal mobility devices (in two-wheeler category) shall have a minimum bay size of 3000 mm x 2400 mm.
- Accessible Car Parking Bay shall have a minimum size of 5000 mm × 3600 mm, which is inclusive of 1200 mm wide side transfer zone
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<td>STAIRS</td>
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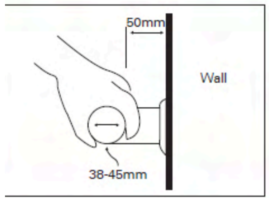

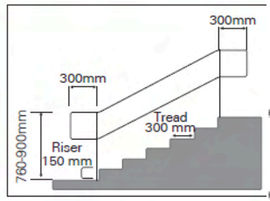

- The steps should have an unobstructed width of at least 1200mm.
- Step risers should be uniform and not be more than 150mm
- Tread (step depth) should be a less than 300mm.
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<tr>
<td>CORRIDOR</td>
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- Corridors should have an unobstructed width of 1200-1800mm, and are well-lit throughout. There should be a thick strip of florescent/ bright coloron both sides of the corridors to help children with low vision in particular navigate their way around.
- External signage should be mounted at 2200mm above the floor for proper head clearance.
- Signage should be mounted at a height of 1000mm from the floor for children aged 6-14 years and at a height of 1400mm-1600mm for children above 14 years of age. Braille signage should be provided on the latch side of the doors.
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<td>SIGNAGE</td>
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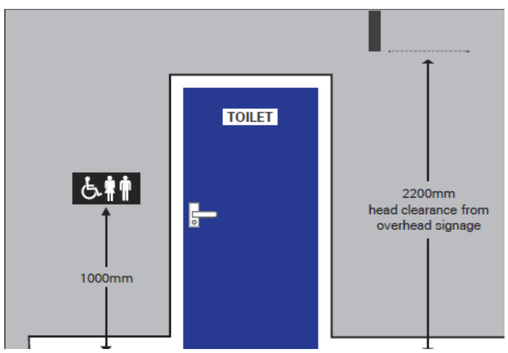

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<td>DESKS AND BENCHES</td>
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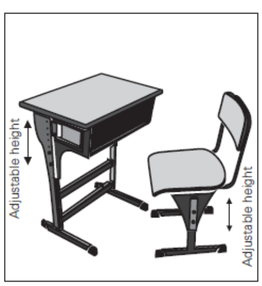

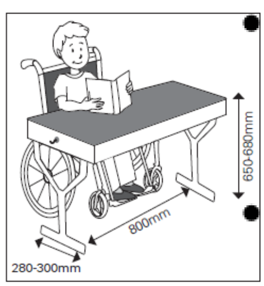

- Tables and desks should not be higher than 800mm, with a minimum knee clearance of 650-680mm (in height) and 280- 300mm (depth) to accommodate wheelchair users.
- The space around tables and desks should be approximately 1200mm x 800mm to facilitate wheelchair maneuvering.
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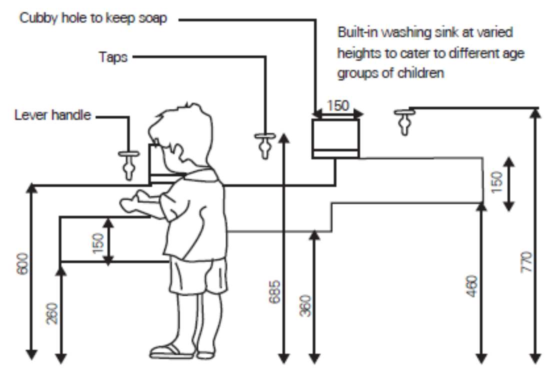
<td>DRINKING WATER UNITS</td>
<td>
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- The drinking water unit should have a washbasin and be accessible with one tap at a height of 400mm and another at 800mm.
- The dimensions of the washbasin should be 520mm x 410mm.

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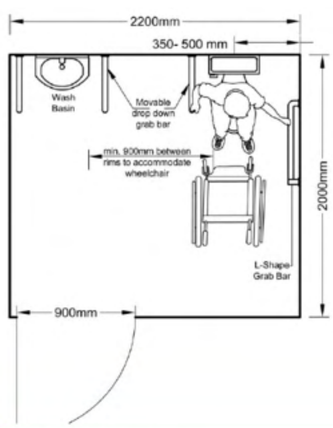
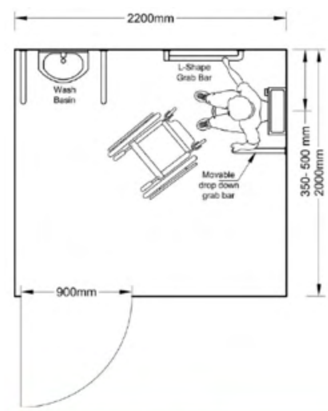
<td>TOILETS (WESTERN COMMODE)</td>
<td colspan="2">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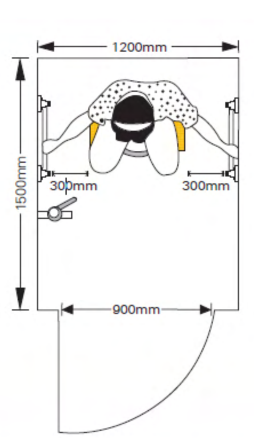
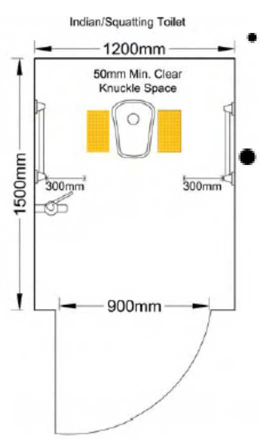
<td>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- The toilet cubicle should be of 1200mm x 1200mm in size (internal size).

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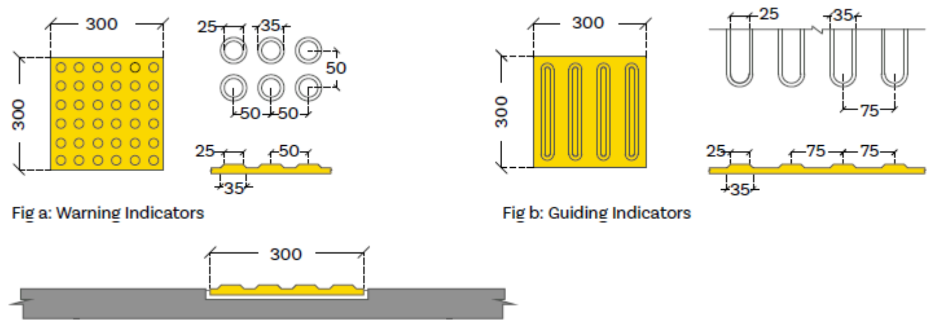
TACTILE PAVERS	 Fig a: Warning Indicators Fig b: Guiding Indicators Fig c: Tactile Paver Section • **Tactile Warning Indicators (Dot type)** Warning indicators warn of either a hazard or a destination. For example, a warning indicator near the edge of a staircase landing As the person approaches the edge, the tactile warning treatment will be identified either by the white cane or underfoot, thus warning of an impending drop to the staircase. • **Tactile Guiding Indicators (Line type)** Tactile guiding or directional indicatorsare used to direct the user from one point to another along a safe path of travel.

CASE STUDIES:COMPARATIVE ANALYSIS

	Secondary Case studies			**Primary Case Studies**	
Parameters	**Hazelwood School**	**School for Blind and Visually Impaired Children**	**Center for the visually blind and impaired Children**	**National Association for the Blind**	**JPM Senior Secondary School**
Location	Glasgow	Gujrat	Mexico	New Delhi	New Delhi
Site Area	2660 sqm	750 sqm	8500 sqm	3456 sqm	4580 sqm
Circulation	Traditional layout with corridors connecting various spaces	Open-plan layout with wide hallways facilitating movement	Central atrium providing easy access to different areas	Design with corridors linking spaces	Open spaces with pathways connecting facilities
Segregation of Vehicular and Pedestrian Movement	Dedicated parking areas away from pedestrian paths	Separate pathways and ramps for pedestrian	Segregated routes for vehicles and pedestrians	Designated drop-off points for safety	Parking areas and pathways are not distinctly separated
Material and Texture	contrasting textures for wayfinding	Tactile surfaces and non-glare finishes	Tactile paving and textured walls	Varied textures for orientation	Non-glare surfaces and tactile pathways
Color Contrast	Moderate use of contrasting colors in	High contrast colors for easy identification	Color schemes optimized for	Emphasis on high contrast in all areas	Strategic use of contrasting colors throughout

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	signage and pathways		visually impaired		
Infrastructure	-Wide corridors -accessible toilets -signage in braille -sensory gardens -textured walls -focused learning rooms -hydro-therapy room	-Braille signage -sensory gardens -textured walls -courtyard next to classroom connecting corridors	-Tactile sense -water channel helps in navigating -sensory gardens -sound and touch gallery -fine arts workshop	-Accessible pathways -audio room -large print materials -accessible library and computer lab -speech therapy room -central court for physical training	-Braille library -hostel facility -workshop and training facilities -Typing classes -hall for recreation and physical education
Community engagement	Collaborations with disability organization - awareness campaigns -Inclusive events	Workshops for parents and teachers,	Community outreach programs, volunteering options, user engagement approach	-Vocational training programs	-Awareness campaigns -workshops for students -learning programs -eco club
Safety Measures	Emergency evacuation plans, Accessible fire alarms. Non-slip flooring	Safety railings, Accessible fire alarms, non-slip flooring	Emergency evacuation plans. Accessible fire alarms, non-slip flooring	Emergency evacuation plans, Accessible fire alarms, non-slip flooring	Safety railings, Accessible fire alarms, non-slip flooring
Tactile Guiding Surface Indicators (TGSIs)	Present	Present	Not Present	Present	Present
Ramps	Not Present	Not Present	Not Present	Present	Not Present
Signages	Adequate and well lit	Adequate and well lit	Adequate and well lit	Adequate and well lit	Inadequate signages
Memory Clues	- Visual cues -color coded systems -visual memory aid	-Tactile cues -Memory aid with textures and smell	-Multi-sensory cues textures and smell	- Audio cues -audio books -tactile cues	-Tactile and auditory cues -braille and audio materials

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RECOMMENDATIONS

1. **Physical Environment**
   - Provide multiple vertical circulation options (stairs, ramps, elevators) to accommodate diverse mobility needs—benefiting users with wheelchairs, crutches, or white canes.
   - Ensure clear, obstruction-free, and legible circulation spaces with level access.
   - Install features such as:
     - Counters at varied heights
     - Fixtures within accessible reach
     - Automatic doors or lever handles
   - Design informal social spaces to encourage interaction, reduce isolation, and foster community—particularly for those with vision or hearing impairments.
2. **Sensory Environment**

Tactile

- Integrate tactile elements in flooring, walls, furniture, and signage (e.g., tactile rails, braille labels) to aid navigation.
- Use “shorelines” (continuous tactile paths) and “landmarks” (interruptions indicating direction changes) for intuitive orientation.

Fig 3 Signage with Braille

Visual

- Signage: Should be placed at dual heights (wheelchair and standing eye levels) with text, braille, and pictograms.
- Colour Contrast:
  - Use high-contrast schemes (70% contrast recommended) to define elements such as door frames, handrails, stairs, and pathways.
  - Warm colours (red, orange, yellow) aid low-vision users in navigation.
- **Lighting:**
  - Combine natural and artificial lighting to enhance visibility and communication (especially lip reading).
  - Avoid glare, reflections, and patterned surfaces to reduce fatigue and prevent seizures.
  - Use matte finishes and task-based lighting to support specific activities and spatial awareness.

Fig 4. Use of graphical representation for more visual communication

3. **Auditory Environment**
   - Use acoustics to provide spatial cues—reflected sounds can indicate room size, corridors, and obstructions.
   - Include auditory landmarks (e.g., water features) to assist orientation.
   - Install hearing loop systems for users with hearing aids.
   - Use auditory signals at entrances and circulation nodes.
   - Incorporate acoustic tiles and carpeting to soften ambient sounds while maintaining some reverberation for spatial awareness.

CONCLUSION

This dissertation aimed to create awareness about the importance of inclusive architecture in educational spaces, emphasizing that children—regardless of ability—are the foundation of a strong and progressive society. Education is a basic right, and visually and hearing-impaired students deserve equal access to learning environments that support their independence and growth. Historically, persons with disabilities, especially those with visual impairments, have been perceived as dependent and marginalized. However,

ISBN 978-93-342-4408-3

their aspirations mirror those of any citizen: equal opportunities, self-reliance, and meaningful contribution to national development.

Through this study, I have understood the real barriers—physical, sensory, and social—that still restrict access for many. Architects play a crucial role in removing these barriers. By following Universal Design principles, inclusive environments can be created without complexity or excessive cost. Educational buildings should address all human senses to ensure dignity, safety, and autonomy for every user.

Ultimately, architecture must serve all. Whether designing new schools or retrofitting existing ones, spaces must be made accessible, legible, and safe for students with sensory impairments. The responsibility lies with architects to design with empathy and foresight—creating environments where every learner can thrive equally and independently.

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ISBN 978-93-342-4408-3

Public-Private Partnership (PPP) Model Projects in Haryana: Viability and the Role of Government

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Abstract

Public-Private Partnerships (PPPs) have become a pivotal strategy for infrastructure development and public service delivery across India. In Haryana, a state experiencing rapid urbanization and industrial growth, the adoption of the PPP model has been positioned as a critical tool to bridge gaps in infrastructure, improve public services, and stimulate economic growth. This paper critically examines the viability of PPP model projects in Haryana, focusing on the effectiveness of government facilitation, the successes achieved, and the persistent challenges encountered.

The government of Haryana has actively promoted PPPs across sectors such as transportation, logistics, energy, education, and food processing. Notable successes include the Kundli-Manesar-Palwal (KMP) Expressway, which has improved regional connectivity and decongested Delhi's road network; the development of Mega Food Parks aimed at boosting agricultural value chains; and the establishment of Multi-Modal Logistics Parks, facilitating efficient goods movement and supply chain integration. In the energy and education sectors, several projects under the PPP framework have sought to enhance service delivery while reducing the financial burden on the state exchequer.

Through a detailed review of project documents, government reports, this paper analyzes the financial, social, and operational dimensions of key PPP initiatives. Findings suggest that while PPPs have enabled timely project completion in several instances, their long-term viability depends on balanced risk-sharing mechanisms, robust regulatory frameworks, and effective monitoring systems. The paper highlights that the government's role is not merely that of a facilitator but also that of a regulator, enforcer, and, when necessary, a direct participant to safeguard public interest.

Despite the promise of PPPs, challenges persist. Issues such as delays in land acquisition, financial restructuring during project execution, inadequate private sector capacity, and ambiguities in contractual agreements have sometimes compromised project outcomes. Furthermore, concerns regarding service quality, transparency in bidding processes, and ensuring equitable access to the benefits of PPP projects remain critical. The paper stresses that a one-size-fits-all approach to PPPs is inappropriate; instead, sector-specific and project-specific strategies are essential for optimizing outcomes.

The paper concludes that PPPs in Haryana have demonstrated significant potential in mobilizing private sector efficiencies and innovation for public benefit, but their success is contingent upon proactive and transparent governance. Government interventions such as fair risk allocation, capacity building of public institutions, strengthening regulatory oversight, and fostering trust between public and private stakeholders are crucial. Going forward, Haryana's experience offers valuable lessons for other Indian states seeking to leverage PPPs for sustainable infrastructure and inclusive economic growth.

Keywords: *Public-Private Partnership, infrastructure development, viability, economic growth*

Introduction

Public-Private Partnerships (PPPs) represent collaborative frameworks between government entities and private sector organizations aimed at financing, designing, and managing public infrastructure projects and services. India's rapid economic growth has driven a surge in demand for infrastructure development, but limited public resources have prompted the exploration of alternative funding and delivery mechanisms, particularly PPPs. Despite the theoretical advantages of PPPs, their practical implementation in India has exposed various challenges, necessitating a thorough evaluation [1, 2].

While PPPs are globally recognized for their potential to deliver infrastructure effectively, the definition of PPPs varies significantly across countries due to differences in political, economic, and social contexts. Although some researchers argue that the concept of PPPs has evolved since ancient civilizations, the term itself has only been in use since the 1970s, gaining traction in the 1990s with the rise of Public Finance Initiatives (PFIs), which became essential for the social and economic landscape of many nations. Despite the diverse definitions, there is broad agreement that PPPs can enhance the economic value of infrastructure outputs and contribute to national development [3, 4].

In the Indian context, the involvement of the private sector is seen as crucial for addressing the gap between infrastructure demand and available investment. The ongoing debate in India regarding the role of PPPs in infrastructure development emphasizes their potential to integrate private sector expertise and resources into the provision of public services. By leveraging the strengths of both the public and private sectors, PPPs are expected to better meet public needs and improve infrastructure standards [5]. In Haryana, a state known for its strategic location and industrial growth, PPP models have been adopted to accelerate infrastructure development and enhance service delivery.

Although PPPs are considered a constructive approach to delivering public services, the concept remains ambiguous, with no universally agreed-upon definition. Scholars and practitioners often emphasize different aspects of PPPs, leading to varying interpretations. The diverse features outlined in Western literature offer valuable insights for further investigation into the dynamics of PPP partnerships [6].

Theoretical Claims and Core Issues

Higher Efficiency Gains: Theoretically, PPPs are believed to achieve higher efficiency in project execution and service delivery due to private sector expertise and innovation. However, efficiency gains remain largely unverified at a macro level. For instance, delays in land acquisition, regulatory clearances,

ISBN 978-93-342-4408-3

and project execution have plagued several PPP projects, undermining their efficiency [1]. The lack of clear guidelines and streamlined processes often leads to cost overruns and project delays.

Value for Money (VfM): The concept of VfM, a cornerstone of PPPs, refers to optimizing resources to achieve the best possible outcomes. While PPPs theoretically offer better VfM by leveraging private sector efficiency, empirical studies have found mixed results. Many projects fail to deliver on VfM due to high upfront costs, inadequate risk-sharing mechanisms, and unforeseen expenses [2]. Additionally, opaque contractual arrangements often result in financial mismanagement and disputes.

Concept of Viability Gap Funding (VGF)

Viability Gap Funding (VGF) is a financial support mechanism introduced by the government to promote infrastructure projects that, while economically beneficial, lack the financial viability to attract private investment. This is often due to high initial capital costs and limited revenue generation in the early stages of the project. VGF serves as a gap-filling solution, enabling such projects to become financially feasible [7].

Under the VGF scheme, the central government provides a grant of up to 20% of the total project cost to support these initiatives. In addition, the sponsoring state government may contribute an additional 20%, effectively reducing the financial burden on private developers and encouraging their participation in infrastructure development [8]. This financial assistance is critical in making large-scale infrastructure projects, such as highways, airports, and urban development projects, more attractive to the private sector, which might otherwise be deterred by the high risks and long payback periods associated with these projects [9].

The VGF model is primarily intended to address market failures by bridging the financial gap between the economic viability of a project and its commercial returns. It encourages the private sector to invest in public infrastructure, ensuring the long-term development of essential services while mitigating financial risks [9].

Overview of the PPP Model in Haryana

The adoption of PPPs in Haryana spans multiple sectors, including transport, energy, education, healthcare, and logistics. The state government, through its PPP policy framework, aims to attract private investment while ensuring the equitable distribution of public benefits. Haryana has made significant strides in fostering Public-Private Partnerships (PPPs) through well-structured frameworks and supportive policies. The Haryana Infrastructure Development Board (HIDB) plays a crucial role in facilitating PPP projects by providing a structured approach to their implementation. HIDB ensures that projects are aligned with the state's infrastructure goals and efficiently managed to deliver desired outcomes. One key mechanism to enhance the financial viability of PPP projects is the Viability Gap Funding (VGF) scheme [9]. The VGF scheme bridges the financial gap for projects that, while socially beneficial, may not be immediately profitable. By providing partial funding, the scheme ensures that essential infrastructure initiatives remain feasible and attractive to private investors. Complementing these efforts, Haryana's PPP policy serves as a comprehensive guide, detailing procedures, risk-sharing mechanisms, and performance monitoring frameworks. This policy framework fosters a collaborative environment, balancing the responsibilities and rewards between the public and private sectors. Collectively, these initiatives underline Haryana's commitment to leveraging PPPs for sustainable infrastructure development.

Viability Analysis of PPP Projects in Haryana

The financial sustainability of Public-Private Partnership (PPP) projects helps in determining their success. For a PPP project to be viable, several factors must be carefully considered to ensure long-term financial stability and optimal performance. These factors include the development of effective revenue models, the provision of government incentives, and the equitable sharing of risks between the public and private sectors.

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a) **Financial Viability**

The success of PPP projects depends on their financial sustainability. Factors contributing to viability include:

Revenue Models: A key aspect of financial sustainability in PPP projects is the establishment of viable revenue models. In many infrastructure projects, revenue generation is critical to ensuring that the project remains self-sustaining over time. For instance, in highway projects, toll collection serves as a primary revenue source, enabling the private partner to recover the costs of investment and operational expenses while generating profits [4]. Similarly, in energy and logistics projects, user charges, such as fees for electricity usage or transportation services, provide a stable income stream for the private entity involved [5]. The design of these revenue models must take into account the demand elasticity, pricing mechanisms, and long-term financial projections to ensure that the revenue is sufficient to cover costs and deliver returns to investors.

Government Incentives: In many cases, government incentives play a significant role in making PPP projects financially attractive to private investors. The government often provides support in the form of grants, subsidies, and tax exemptions to reduce the financial burden on private sector participants. A widely used incentive in India is the Viability Gap Funding (VGF) scheme, which is designed to bridge the gap between the project's cost and the expected revenue, thereby making it more feasible for private investors to participate in projects that might otherwise be deemed financially unviable [1]. Additionally, tax exemptions and other financial incentives can encourage private investment by reducing the overall financial burden on the investor, thus improving the project's profitability and sustainability [2].

Risk Sharing: Another critical factor in the success of PPP projects is the equitable distribution of risks between the public and private partners. In PPP contracts, risk sharing is essential to ensure that both parties have aligned incentives and that the project remains financially viable throughout its lifecycle. Risk sharing refers to the allocation of financial and operational risks, such as construction delays, cost overruns, or revenue shortfalls, in a manner that is fair and proportionate to the ability of each party to manage the risks [6]. For instance, while the private partner may assume responsibility for construction and operation, the public sector may absorb risks related to policy changes, regulatory hurdles, or unforeseen circumstances. This division of responsibility helps create a balanced approach, where both parties are incentivized to work toward the success of the project while mitigating their exposure to adverse financial consequences [3].

b) **Social Viability:** The social viability of Public-Private Partnerships (PPPs) is a critical factor in their success, as these projects often aim to address significant societal needs, particularly in underserved areas. One of the core advantages of PPPs is their ability to contribute to social development by improving access to essential services such as healthcare, education, and infrastructure. Projects like rural healthcare centers and educational institutions are prime examples of how PPPs can address critical gaps in service provision, particularly in areas where the government may have limited resources or capacity to act independently [4].

c) **Operational Viability:** Operational viability is equally essential for the long-term success of PPP projects. Effective management and performance monitoring are key to ensuring that the project delivers its intended outcomes efficiently. Innovations in technology and management practices have played a pivotal role in enhancing the operational efficiency of PPPs, particularly in sectors like logistics and energy, where efficient operations are critical to meeting demand and sustaining profitability [6,4].

d) In the logistics sector, for example, technological advancements such as real-time tracking systems and automated warehousing have significantly improved operational efficiency. These innovations help reduce costs, improve service delivery, and ensure that the infrastructure developed under a PPP is used to its full potential (Grimsey & Lewis, 2004). Similarly, in the energy sector, advancements in renewable energy technologies, coupled with efficient grid management and monitoring systems, have

ISBN 978-93-342-4408-3

improved the operational performance of energy-related PPPs. By implementing these innovations, both the private and public partners can ensure that the project remains sustainable and that the services provided are reliable, cost-effective, and able to meet the growing demands of the population (Kumar et al., 2020).

Efficient management and performance monitoring ensure the long-term success of PPP projects. Innovations in technology and management practices have enhanced operational efficiency in sectors like logistics and energy.

Role of Government in PPP Models

In Haryana, Public-Private Partnerships (PPPs) have been instrumental in advancing infrastructure and public services. The state's government plays a pivotal role in these collaborations, primarily as a facilitator and regulator, ensuring that projects align with public interests and standards.

Regulatory Oversight: The Haryana government establishes the legal and regulatory framework for PPPs, ensuring that projects comply with state laws and policies. This oversight includes monitoring project quality, adherence to timelines, and the use of appropriate materials.

Project Identification and Facilitation: The government identifies sectors where PPPs can be beneficial, such as transport, education, and healthcare. It facilitates the development of these projects by providing necessary approvals, land acquisition, and other logistical support.

Financial Support and Incentives: To attract private investment, the Haryana government may offer financial incentives, including viability gap funding, subsidies, or tax exemptions. These measures aim to make projects more attractive to private partners.

Monitoring and Evaluation: The government monitors the performance of PPP projects to ensure they meet agreed-upon standards and deliver the intended public benefits. This includes regular audits and assessments to evaluate the project's impact and efficiency.

Government Stake in PPP Projects in Haryana

The specific percentage of government stakes in PPP projects in Haryana varies depending on the nature of the project and the terms of the partnership agreement. In some cases, the government may hold a minority stake, while in others, it may be a majority stakeholder. For instance, in the transport sector, the government often retains significant control to ensure public interests are safeguarded. For example, the Haryana government has initiated several PPP projects, including six completed projects worth ₹114.94 crore and 21 ongoing projects with an estimated cost of about ₹643.36 crore. These projects span various sectors, reflecting the government's strategic approach to infrastructure development through PPPs.

Project Name	Total Project Cost	VGF Allocation	VGA Percentage of Total Cost	Key Features/ Outcomes	Scheme Under Which Allocated	Success or not	References
1. Dwarka Expressway	₹4,000 crore	₹1,000 crore	25%	- Enhanced connectivity between Delhi and Gurgaon. - Reduced traffic congestion on NH-8. - Improved property value.	National Highways Authority of India (NHAI) VGF Scheme	Success: Project completed, reducing traffic and boosting economic growth.	NHAI Annual Report, MoRTH publications

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2. Yamuna Expressway	₹5,500 crore	₹1,500 crore	27.27%	- Improved transport from Delhi to Agra. - Contributed to tourism and trade.	Ministry of Road Transport & Highways (MoRTH)	Success: Expressway is operational, promoting economic and tourism growth.	Government of Haryana, MoRTH Reports
3. Faridabad-Gurgaon Road Corridor	₹2,500 crore	₹500 crore	20%	- Eased connectivity between Faridabad and Gurgaon. - Alleviated traffic bottlenecks.	National Highway Development Project (NHDP) VGF	Success: The road corridor significantly improved commuting times.	Haryana State Government, MoRTH Reports
4. Rajiv Gandhi Education City	₹1,000 crore	₹200 crore	20%	- Created a hub for higher education. - Attracted universities and research institutions.	State-level VGF Scheme	Partial Success: The city is operational, but challenges remain in expanding the student base.	Haryana Urban Development Authority (HUDA)
5. Industrial Model Township (IMT) Manesar	₹1,200 crore	₹250 crore	20.83%	- Boosted industrial growth and job creation. - Attracted large-scale manufacturers and industries.	Haryana Industrial Policy VGF Scheme	Success: The township has become a key industrial area in Haryana.	HUDA, Haryana State Govt. Reports
6. Solar Power Projects (Various Locations)	₹1,500 crore	₹300 crore	20%	- Promoted renewable energy generation. - Reduced dependence on non-renewable energy sources.	National Solar Mission (NSM) VGF	Success: Renewable energy capacity has increased, meeting energy goals.	Ministry of New and Renewable Energy (MNRE)
7. Haryana State Data Centre	₹150 crore	₹50 crore	33.33%	- Enhanced state-level e-governance. - Improved data storage and management.	National e-Governance Plan (NeGP)	Success: Strengthened Haryana's digital infrastructure.	Government of Haryana e-Governance Reports
8. Gurgaon Integrated Transport System	₹2,000 crore	₹700 crore	35%	- Improved public transport. - Reduced	Urban Transport Fund under	Success: Improved transport efficiency	Ministry of Housing & Urban

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				traffic congestion. - Enhanced connectivity within Gurgaon.	Smart Cities Mission	and reduced congestion.	Affairs Reports
9. Kundli Industrial Area Developmen t	₹500 crore	₹100 crore	20%	- Promoted industrial development. - Generated employment opportunities.	Haryana Infrastructur e Developmen t Scheme (HIDS)	Success: The industrial area has become an investment hotspot.	State Government Infrastructure Reports
10. Manesar Industrial Park	₹600 crore	₹200 crore	33.33%	- Attracted major industries. - Contributed to Haryana's industrial growth.	Industrial Infrastructur e Developmen t Fund (IIDF)	Success: The park has established itself as a key industrial hub.	Haryana Urban Development Authority (HUDA)
11. Mewat Eco-Tourism Project	₹150 crore	₹75 crore	50%	- Created job opportunities in eco-tourism. - Boosted tourism in the region.	State-level Eco-Tourism Developmen t Scheme	Partial Success: The project is progressing but has faced challenges in attracting sufficient tourism.	Haryana Tourism Department Reports
12. Haryana Health Infrastructur e Project	₹700 crore	₹300 crore	42.86%	- Upgraded healthcare facilities. - Improved access to healthcare in rural and urban areas	National Health Mission (NHM) VGF Scheme	Success: Improved healthcare facilities and accessibility.	Ministry of Health and Family Welfare Reports
13. Rewari Integrated Water Supply Project	₹100 crore	₹50 crore	50%	- Ensured continuous water supply to Rewari. - Improved sanitation and water quality.	Swachh Bharat Mission VGF Scheme	Success: Reliable water supply system has been established.	Ministry of Housing and Urban Affairs Reports
14. Bhivpuri Wastewater Treatment Plant	₹300 crore	₹150 crore	50%	- Improved wastewater treatment capacity. - Reduced environmental pollution in the region.	National Urban Developmen t Mission	Success: Enhanced sanitation and waste management infrastructure .	Ministry of Urban Development , Haryana Govt.

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15. Ambala-Rohtak Road Corridor	₹1,000 crore	₹100 crore	10%	- Enhanced connectivity between key cities. - Reduced travel time and traffic congestion.	National Highways VGF Scheme	Success: Road corridor operational, facilitating faster travel and trade.	Ministry of Road Transport & Highways Reports
16. Sonepat Industrial Corridor	₹800 crore	₹200 crore	25%	- Boosted industrialization. - Created job opportunities in manufacturing and services.	Haryana Infrastructure Development Fund (HIDF)	Success: The industrial corridor has become a significant economic area.	Haryana State Government Reports
17. Gurgaon Waste Management Project	₹300 crore	₹75 crore	25%	- Improved waste collection, segregation, and recycling. - Reduced landfill usage.	Smart Cities Mission VGF Scheme	Success: The waste management project is operational and improving sanitation.	Gurgaon Municipal Corporation Reports
18. Rohtak Industrial Park	₹1,000 crore	₹250 crore	25%	- Promoted local industry and manufacturing. - Created jobs and attracted investment.	Haryana Industrial Policy VGF Scheme	Success: The industrial park is operational, contributing to local economic development.	Haryana Urban Development Authority (HUDA)
19. Hisar-Sirsa Road Project	₹500 crore	₹100 crore	20%	- Improved road infrastructure. - Reduced travel time between Hisar and Sirsa.	National Highways VGF Scheme	Success: Improved transportation efficiency and connectivity.	Ministry of Road Transport & Highways Reports
20. Karnal Industrial Area Development	₹700 crore	₹150 crore	21.43%	- Attracted industries. - Supported job creation in the region.	Haryana State Industrial Development Fund (HSIDF)	Success: The area has become an industrial hub, driving local development.	Haryana Industrial Development Corporation

Table 1 Key PPP infrastructure projects in Haryana under the Public-Private Partnership (PPP) model, detailing their VGF model, description, outcomes, and success status the fund allocated under Viability Gap Assistance (VGA) and the total cost of each project (Source: Author)

Notes:

1. **VGA Allocation:** The amount of funding provided by the government through the Viability Gap Assistance scheme, usually covering a percentage of the total cost.

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2. **Total Project Cost:** This represents the total estimated cost of the infrastructure or development project.
3. **VGA Percentage:** This percentage is calculated based on the ratio of VGA allocation to total project cost.
4. **Scheme References:** The projects are funded under various government schemes such as the National Highways Authority of India (NHAI) VGF Scheme, Smart Cities Mission, National Solar Mission, etc.

Challenges in Implementing PPPs in Haryana

Implementing Public-Private Partnerships (PPPs) in Haryana, like in many other regions, presents a range of challenges that can hinder the successful realization of infrastructure projects. These challenges stem from various factors, including financial, institutional, and social considerations, and require careful planning and management to address. Below are some of the key challenges faced in the implementation of PPPs in Haryana:

1. Regulatory and Institutional Barriers

- **Complex Approval Processes**: One of the primary challenges in implementing PPP projects is the lengthy and often complex approval process. The involvement of multiple government departments and agencies can lead to delays in project initiation and approval, discouraging potential private investors [11].
- **Lack of Clear Guidelines**: Sometimes, the legal and regulatory framework governing PPPs is unclear. While the Haryana government has established frameworks, inconsistency in applying these policies across different sectors can create confusion among private stakeholders [12].

2. Financial and Funding Constraints

- **Risk Allocation**: One of the major concerns for private sector participants is the distribution of risks between public and private partners. In some cases, the government may not provide sufficient guarantees or financial support, making private companies hesitant to invest [2].
- **Funding Constraints**: Limited public funds for infrastructure projects can be a barrier, especially in cases where private sector participation is needed to bridge the investment gap. Although the government offers financial incentives such as viability gap funding (VGF), securing sufficient funds from both sectors can be challenging [7].

3. Land Acquisition Issues

- **Land Acquisition Delays**: Land acquisition is a critical aspect of most infrastructure projects, and in Haryana, land acquisition issues often cause significant delays. The time-consuming process of acquiring land, especially in urban areas, can stall PPP projects and disrupt project timelines [5].
- **Disputes Over Land Ownership**: In some cases, disputes related to land ownership and compensation can lead to legal challenges, further complicating the progress of PPP projects [7].

4. Political and Social Factors

- **Political Instability**: Changes in political leadership or policies can create uncertainties for PPP projects. A shift in government priorities can lead to the suspension or cancellation of ongoing projects, affecting investor confidence [1].
- **Public Resistance**: Local communities sometimes resist PPP projects, especially when they involve land acquisition or changes to the existing infrastructure. This resistance can be fueled by concerns about the social and environmental impact of the projects, leading to protests or delays [2].

5. Poor Project Structuring and Management

- **Inadequate Feasibility Studies**: In some cases, the lack of proper feasibility studies or inaccurate market assessments can lead to the failure of PPP projects. This may result in cost overruns, delays, and suboptimal outcomes [12].
- **Operational and Performance Monitoring Issues**: Effective monitoring of project progress and performance is crucial for the success of PPPs. However, there are instances where the lack of effective monitoring systems and performance metrics has resulted in inefficiencies in the operation of these projects [7].

6. Legal and Contractual Challenges

- **Ambiguous Contract Terms**: Sometimes, the terms and conditions set out in PPP contracts can be ambiguous, leading to disagreements between public and private partners during the implementation phase. This includes issues regarding performance standards, payment mechanisms, and dispute resolution [5].
- **Enforcement of Contracts**: Even when clear contractual terms are established, ensuring that both parties meet their obligations can be challenging, particularly in cases where there is insufficient legal infrastructure for enforcing agreements [2].

7. Market Risks and Competition

- **Market Volatility**: The volatility of the market, especially in sectors like energy, transportation, and logistics, can affect the financial viability of PPP projects. Changes in global prices or demand for services can make it difficult for private partners to meet profitability expectations [12].
- **Sectoral Competition**: In some cases, the involvement of multiple private players in a sector can lead to unhealthy competition, affecting the sustainability of the projects and potentially lowering service quality or raising costs [2].

Public-Private Partnerships (PPPs) have the potential to significantly contribute to infrastructure development in Haryana. However, to fully realize their benefits, it is essential to address several challenges and improve the existing PPP framework. The following recommendations aim to enhance the effectiveness and sustainability of PPP models in the state.

Strengthening Policy Frameworks

A robust and clear policy framework is essential to the success of PPP projects. To strengthen the policy landscape in Haryana, it is recommended that:

a) **Regular Policy Updates**: The PPP policy should be regularly updated to align with emerging national and international best practices. This includes adapting to new technological advancements, evolving market dynamics, and changes in government priorities. By doing so, the policy will remain relevant and capable of addressing emerging challenges in infrastructure development.

b) **Alignment with National Guidelines**: Haryana should ensure that its PPP policies are in harmony with national guidelines, such as the National PPP Policy and the Model Concession Agreement (MCA). This alignment would help standardize practices, reduce regulatory inconsistencies, and improve the state's attractiveness to private investors [10].

c) **Clear Governance Structure**: The state should establish a centralized PPP cell with a clear mandate and resources to oversee and manage PPP projects. This cell should be responsible for providing guidance, support, and conflict resolution to public and private stakeholders throughout the project lifecycle [7].

Promoting Transparency

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Transparency is crucial for gaining the trust of both private investors and the public. To enhance transparency in Haryana's PPP projects, the following actions should be taken:

a) **Digital Monitoring Tools**: The government should adopt advanced digital tools and platforms for project monitoring, ensuring that all project data (financial performance, milestones, and outcomes) is publicly available. These platforms can provide real-time updates on project progress, help in tracking budgets, and allow for transparent auditing [2].

b) **Public Feedback Mechanisms**: Implementing public feedback channels through digital platforms or public consultations can significantly enhance transparency. These mechanisms will allow citizens to voice concerns, suggest improvements, and monitor the impact of PPP projects in their communities. Public participation can also reduce the likelihood of corruption and ensure that projects are implemented in the best interest of the public [5].

c) **Clear Reporting Standards**: Establishing standardized reporting norms for both the public and private partners can help monitor project performance, manage expectations, and ensure accountability throughout the life of a PPP agreement [12].

Encouraging Private Investment

The involvement of the private sector is critical to the success of PPPs in Haryana, as it can help bridge the funding gap for infrastructure projects. To encourage more private investment, the following measures should be considered:

a) **Tax Incentives and Financial Support**: The state government should offer tax incentives, such as exemptions or reductions in corporate taxes, to attract private investors. In addition, the government can provide financial incentives, such as Viability Gap Funding (VGF), to make PPP projects more financially viable, particularly in sectors like healthcare, education, and transportation where returns may take longer to materialize [7].

b) **Reducing Procedural Delays**: One of the key barriers to private sector participation in PPP projects is bureaucratic delays. By simplifying approval processes, streamlining procedures, and reducing red tape, Haryana can create a more conducive environment for private investment. Fast-tracking land acquisition and approvals for infrastructure projects would also help attract private investors [1].

c) **Comprehensive Risk Mitigation Mechanisms**: Establishing clear risk-sharing mechanisms can encourage private participation. The government should be transparent about the risks involved and offer measures to mitigate those risks. This can include guarantees for revenue generation, currency exchange protection, or providing a stable regulatory environment to ensure that private partners have confidence in long-term investments [2].

Enhancing Community Engagement

For PPP projects to succeed, it is essential to ensure that they meet the needs of the communities they serve. This requires engaging with stakeholders and fostering public support. The following strategies can be used to enhance community engagement in PPP projects:

a) **Public Awareness Campaigns**: To ensure that local communities are informed and supportive of PPP projects, the Haryana government should launch public awareness campaigns that explain the benefits of PPPs and their potential impact on local infrastructure. These campaigns should be multi-faceted, using digital media, town hall meetings, and local outreach programs to reach diverse community groups [12].

b) **Stakeholder Consultations**: Before the initiation of any major PPP project, the government should conduct thorough consultations with relevant stakeholders, including local communities, civil society organizations, and subject matter experts. These consultations can help identify potential concerns,

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prioritize community needs, and ensure that the project design takes into account the social, environmental, and economic impacts on the population [11].

c) **Inclusive Development Practices**: PPP projects should be designed in a way that benefits all sections of society, including marginalized and underserved communities. The government should ensure that these communities are actively involved in the project planning and decision-making processes, and that their concerns are addressed in the final design and implementation [7].

Conclusion

The importance of Public-Private Partnerships (PPPs) in addressing India's infrastructure development needs amidst constrained public resources. PPPs, while theoretically offering efficiency, value for money (VfM), and innovation, face practical challenges in implementation. Ambiguities in definition, inefficiencies in project execution, and mixed results in delivering VfM indicate the need for a more nuanced understanding and tailored approach to PPPs in India.

The Viability Gap Funding (VGF) projects in Haryana in supporting infrastructure, industrial, and social development initiatives. Projects such as the Dwarka Expressway, Yamuna Expressway, and Ambala-Rohtak Road Corridor have significantly enhanced connectivity, reduced congestion, and contributed to economic growth. Industrial ventures like the Manesar Industrial Park and Sonepat Industrial Corridor have driven industrialization, created jobs, and attracted investments. The VGF scheme's adaptability is evident in its support for diverse sectors, including renewable energy, waste management, healthcare, and urban services. While most projects were successful in achieving their objectives, a few, like the Rajiv Gandhi Education City and Mewat Eco-Tourism Project, faced challenges in reaching their full potential, indicating the need for improved planning and execution strategies. Sustainability-focused projects, such as those under the National Solar Mission and Smart Cities Mission, highlight efforts to reduce environmental impact and promote resource efficiency. VGF allocations have been efficiently utilized, with proportional funding provided to projects with significant financial gaps. The alignment of these projects with state and national schemes ensures coherence with broader developmental goals. Overall, VGF has proven to be a critical tool for bridging financial gaps, fostering socio-economic growth, and advancing Haryana's development agenda.

Discussions

Public-Private Partnerships (PPPs) processes of modern infrastructure development, offering the promise of efficiency and innovation. However, their real- world application presents complexities. In India, the absence of a universally accepted PPP definition leads to varied interpretations and challenges in implementation. Despite their potential to address infrastructure gaps, PPPs in India often face inefficiencies due to delays in land acquisition, regulatory clearances, and cost overruns.

Haryana's approach to PPPs illustrates both successes and challenges. Projects such as the KMP Expressway and Multi-Modal Logistics Parks demonstrate how PPPs can enhance connectivity and optimize supply chains. The adoption of Viability Gap Funding and a clear PPP policy framework has been pivotal. However, unresolved issues, including land acquisition disputes and unclear risk allocation, highlight areas needing improvement.

Theoretically, PPPs offer higher efficiency gains and VfM. Yet, these outcomes are often compromised in practice due to opaque contracts and inadequate monitoring mechanisms. Social viability, an often-overlooked aspect, deserves attention, particularly in projects aimed at improving healthcare and education access. Operational viability is equally critical, requiring advanced technology and robust management practices to ensure project success. The government must refine its role as a facilitator and regulator. Comprehensive reforms are needed to streamline approvals, ensure transparent risk-sharing, and develop robust monitoring frameworks. Strengthening public trust in PPPs through transparency and stakeholder engagement is equally vital.

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ISBN 978-93-342-4408-3

Exploration of Fleeting Architecture

"Parivartan sansar ka niyam hai. (Change is the rule of the world.) - Lord Krishna"

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Abstract

Fleeting architecture, often seen as temporary and inconsequential, plays a crucial role in responding to evolving societal needs and cultural shifts. This dissertation critically examines its socio-cultural impact, highlighting how temporary structures adapt to changing demographics, address urban challenges, and foster social interaction. Employing an interdisciplinary approach—drawing from architecture, cultural studies, and sociology—it explores how such interventions catalyze community building, cultural innovation, and the reimagining of public space. Through detailed case studies ranging from festival installations to transient community spaces, the research reveals how temporary architecture enables the articulation of cultural identities, negotiation of social norms, and performance of collective memories. By analyzing the interplay of design, materiality, and socio-cultural context, this study positions fleeting architecture as a vital tool for cultural expression and societal engagement. Beyond functionality, it serves as a dynamic medium through which contemporary cultural landscapes are understood, shaped, and experienced.

Keywords : *Fleeting Architecture, Temporary Structures, Cultural Memory, Festival Infrastructure, Modular Design, Adaptive Spaces,Sustainable Design.*

Introduction

Fleeting architecture is a form of temporary architecture focused on creating transient, sensory, and time-bound spatial experiences. Designed to be dismantled or repurposed, it offers flexibility, sustainability, and cost-effectiveness, with roots tracing from nomadic shelters to modern pop-up structures and event pavilions. It embraces impermanence as a design strength, offering agile solutions that respond swiftly to evolving spatial, cultural, and environmental contexts. Its true value lies in its ability to create meaningful, immersive experiences while promoting innovation, sustainability, and inclusivity within a temporary framework. Fleeting architecture responds to immediate human needs—social, ceremonial, spiritual, and commercial. From nomadic tents to inflatable pavilions, temporality is expressed in four main ways: **functional setups** (shelters, sanitation, food zones), **relocatable units** (pods, kiosks), **single-use elements** (festival art, altars), and **material-based forms** using bamboo, canvas, FRP, or recycled materials. Fleeting architecture represents a dynamic branch of temporary architecture that prioritizes short-lived yet impactful spatial experiences. It adapts quickly to changing contexts, serving immediate human needs—whether ceremonial, social, spiritual, or commercial—through structures that are mobile, modular, or event-specific.

The importance of fleeting structures

Climate Response : Temporary structures offer a valuable platform for experimentation and learning, as highlighted by Lévesque (2007). Unlike permanent constructions, these structures allow closer engagement with the site and community, promoting interaction and responsiveness. Their impermanence makes them naturally adaptable, open to change, and capable of accommodating improvisation. Festivals, for instance, alter our perception of time, breaking routine and enabling spontaneous experiences that inspire new possibilities. This makes temporary architecture ideal for testing ideas before committing to permanent, resource-intensive constructions, especially in the context of sustainability.

Reusing and Recycling : Temporary buildings support a "try before you buy" approach in architecture, allowing planners and designers to assess how a space functions before making long-term decisions. This can prevent wasteful investments in large, eco-friendly buildings that might end up being poorly located or

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underused. Moreover, temporary structures are inherently flexible and can be reused, relocated, or modified as needed. They typically consume fewer materials and energy, making them a more resource-efficient and environmentally responsible alternative.

Local Collaboration in Fleeting Architecture: Fleeting architecture often thrives on collaboration with local communities. These projects benefit greatly from local knowledge, which can help in creating culturally relevant and context-sensitive designs. By engaging local people, construction teams can avoid costly mistakes, improve efficiency, and discover more innovative, community-rooted solutions. Such collaboration also strengthens the relationship between the built environment and its users, fostering a sense of ownership and shared purpose.

Space Utilization in an Efficient Manner : Temporary structures are designed to be compact, multifunctional, and flexible, making the most of limited space. Every design element is thoughtfully planned to ensure maximum utility with minimal waste. This efficiency is especially critical in high-density urban settings or temporary event spaces, where speed of installation, adaptability, and optimized spatial use are essential. Their modular and scalable nature allows them to adjust quickly to changing needs and conditions.

Objectives

- To document and analyze the evolution of temporary architectural forms over time.
- To explore innovative types of temporary structures used in large-scale, short-duration events within the field of temporary architecture.
- To focus on the diverse typologies of temporary structures employed during the events held for the period.
- Evaluating material usage - To explore the range of materials used in temporary architecture, with a focus on sustainability and reusability.
- Exploring the construction techniques used for fast, modular, and efficient temporary structures.

Methodology

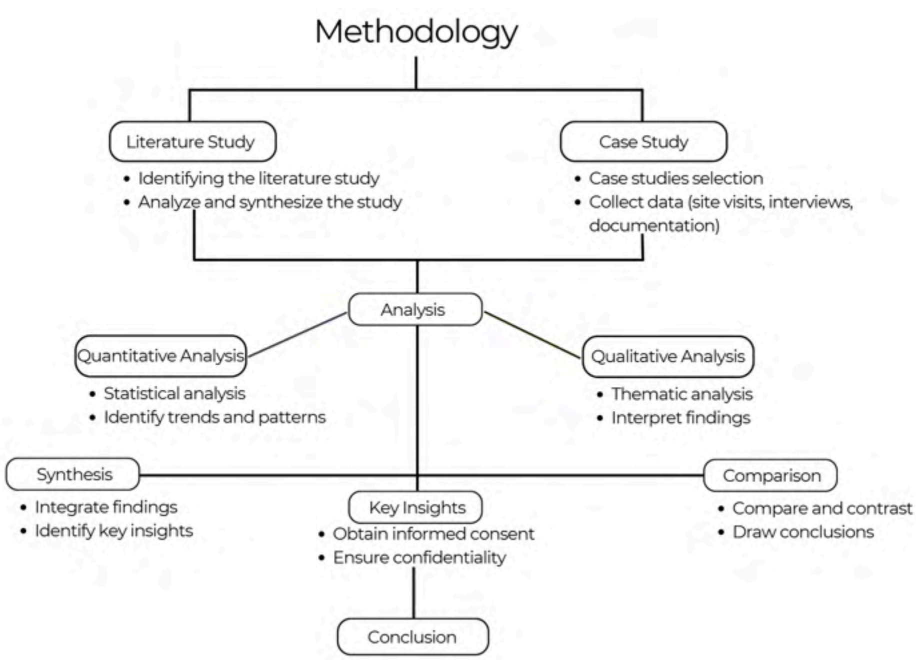

Fig 1. Flowchart (Source : Author)

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Case Study - 1 : Mahakumbh Mela (Prayagraj)

The **Mahakumbh Mela 2025** in Prayagraj is an unparalleled **temporary urbanism** case study, covering **4000 hectares**. Occurring every 144 years, this massive Hindu pilgrimage transforms into a functional city with robust temporary infrastructure. Key elements include **30 pontoon bridges**, **28,100 sanitation units** (toilets/urinals), and **23 temporary hospitals** staffed with medical personnel. It accommodates millions of pilgrims in over **150,000 tents** across various luxury levels, accessing **12 km of bathing ghats**.

The Mela exemplifies efficient, adaptive urban management, integrating modern technology for navigation and safety, and providing vibrant cultural spaces like **Kalagram and diverse exhibitions.** Temporary structures are constructed using a **mix of steel, bamboo,wood, tarpaulin, eco-fabrics, and modular materials**, ensuring rapid assembly, climate response, and sustainable reuse. These structures balance functionality with cultural expression, creating a temporary yet immersive urban experience. It is a live laboratory for urban innovation, emergency planning, and large-scale crowd management. The scale, speed, and coordination involved offer valuable lessons for future disaster relief and temporary settlement design. The planning reflects deep coordination between government agencies, designers, and spiritual stakeholders. Each element is designed to be disassembled and repurposed post-event, leaving minimal environmental impact. The temporary city operates on a well-organized grid with signage, water supply, waste disposal, and power lines laid out like a permanent township. Despite its scale and impermanence, the Mela demonstrates how strategic design and planning can uphold safety, hygiene, and user comfort even under intense pressure.

Fig 2. Bathing Ghats

Fig 3. Medical hospitals

Fig 4. Pink plastic toilets for women

The Mahakumbh Mela draws a vast and diverse population of over **660 million visitors** throughout its duration. Daily footfall ranges from **1 to 8 million**, with peaks on auspicious bathing days such as Mauni Amavasya and Basant Panchami. Attendees include sadhus, saints, spiritual seekers, devotees, tourists, families, and researchers from various socio-economic backgrounds. Accommodation options—from basic tents to luxury camps—cater to this diversity, reflecting the inclusive and large-scale nature of the event.

Fig 5. Pilgrim attendance at Mahakumbh Mela

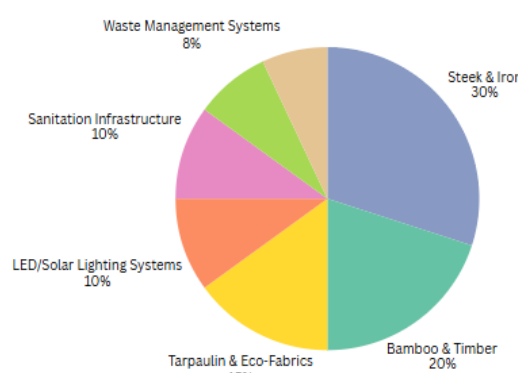

Fig 6. Material usage distribution

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Case Study - 2 : Pushkar Camel Fair (Rajasthan)

The Pushkar Camel Fair in Rajasthan is a prime example of temporary urbanism, an annual week-long event centered on **large-scale livestock trading and the Kartik Poornima festival**. It showcases the spontaneous creation of a vibrant, functional city, utilizing local materials and traditional construction for quick assembly. Materials used for the temporary setup include **bamboo, wooden poles, canvas, tarpaulin, rope, jute, thatch, and locally sourced mud, ensuring low-cost, climate-responsive, and culturally rooted construction.**

This temporary settlement features diverse tented accommodations, market stalls, livestock enclosures, and essential services like temporary medical facilities, sanitation, and cultural performance areas. **Its layout is carefully zoned to manage crowds, ensure safety, and provide seamless access to services and activities.** The fair demonstrates how a community can efficiently create a dynamic urban environment for a large, transient population, blending economic, religious, and cultural functions.

Fig 7. Pushkar Fair

Fig 8. Horse & Camels showing fun

The event attracts over **200,000 visitors annually**, including livestock traders, rural families, Hindu pilgrims, foreign tourists, photographers, and cultural enthusiasts. The fair sees its peak attendance around **Kartik Poornima**, when the religious significance of the sacred Pushkar Lake draws thousands of pilgrims for ritual bathing, creating a vibrant confluence of commerce, spirituality, and cultural celebration. In 2025, the Pushkar Camel Fair recorded its peak attendance of approximately 60,000 visitors on Kartik Poornima, marking it as the highest footfall day of the event.

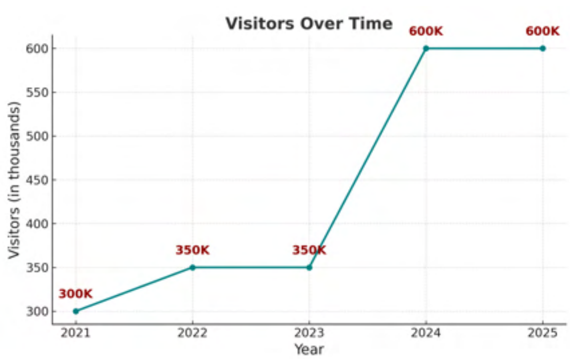

Fig 9. Pilgrim attendance at Mela

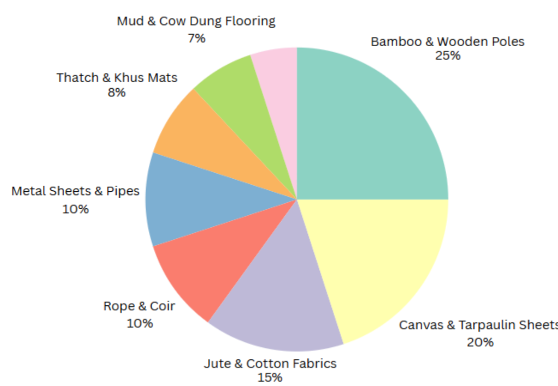

Fig 10. Material usage distribution

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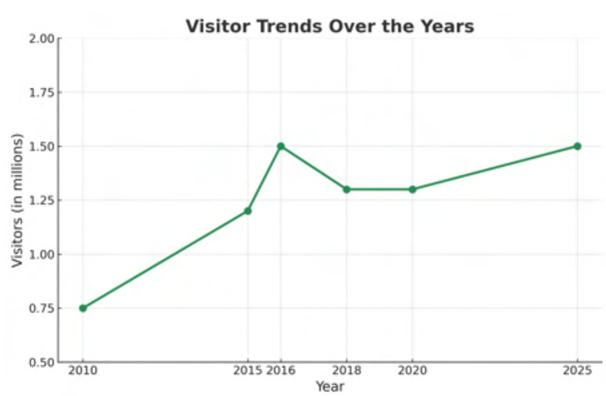
Case Study - 3 : Surajkund Mela (Faridabad)

The Surajkund International Crafts Mela, held annually in February, spans a 40-acre site in Faridabad and attracts a diverse crowd of over **1.2 million visitors**. It serves as a practical showcase of culturally rooted temporary architecture, featuring more than 1,000 temporary stalls constructed through 150+ formal tenders. Hosting over **4,000 artisans from 30 countries and 20 Indian states**, the mela is organized into themed zones reflecting its yearly partner nations.
They are constructed using bamboo, wood, thatch, khus mats, jute, canvas, rope, mud plaster, fabric panels, and solar lighting—blending traditional materials with modular, eco-conscious design. These structures are dismantled and reused each year, demonstrating resource efficiency and low environmental impact. The vibrant spatial layout enhances visitor experience while preserving the vernacular character of each participating region.

Fig 11. Celebrating craft and culture *Fig 12. Cultural entertainments at the mela*

Key infrastructure includes 200+ food stalls, four main performance venues, and a centralized service hub equipped with 200+ CCTV cameras, a police post, and a dispensary to ensure public safety. **The mela's signature attraction, Apna Ghar, alone receives over 50,000 visitors, highlighting its compelling blend of culture, craft, and tactical urban design.** The event generates significant economic activity for local artisans, food vendors, and transport services. Additionally, efforts such as eco-friendly stall materials, waste segregation, and energy-efficient lighting reflect a growing emphasis on sustainable event practices.



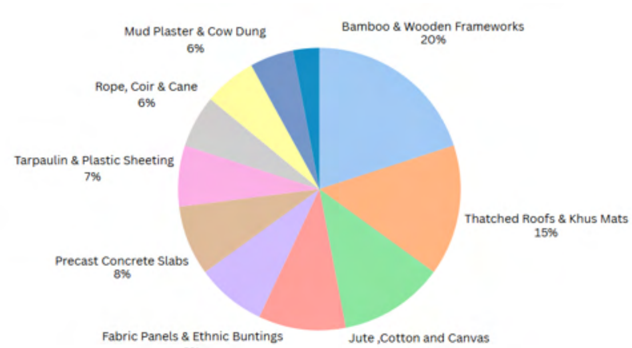


Fig 13. Visitors' attendance at Surajkund Mela *Fig 14. Material usage distribution*

Case Study - 4 : Dubai Expo 2020 (UAE)

The **Dubai Expo 2020** (2021-22) was a pivotal case study in **sustainable temporary architecture**, spanning **438 hectares** and attracting **over 24 million visitors** from 192 countries. Its core achievement was the **80% post-event repurposing into Expo City Dubai**, demonstrating a strong legacy and circular

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design principles for large-scale events. The concourse pergola system, made from **lightweight, recyclable materials**, provided shaded walkways while reducing urban heat gain. The Singapore Pavilion showcased a **net-zero energy rainforest experience**, integrating solar panels, natural ventilation, and vertical greenery into a self-sustaining structure. Many pavilions were designed with disassembly and relocation in mind, promoting material reuse and minimal construction waste. The event also featured smart infrastructure, including AI-based crowd control, autonomous transport pods, and interactive digital wayfinding systems.


Fig 15. Entrance gateway


Fig 16. Concourse Pergola


Fig 17. Singapore Pavilion

The Expo's temporary structures pushed innovation, featuring the **world's longest textile sunshade**, pavilions built from **leased, reusable steel and mycelium**, **inflatable ETFE designs with solar panels**, and **kinetic sunshades**. Iconic pavilions like the UAE's falcon-inspired design with **movable, solar-integrated wings** exemplified energy efficiency and minimal environmental impact, redefining temporary, impactful construction.

Designed for life beyond the fair, the site's intentional "build-to-rebuild" strategy has already enabled repurposing more than 80 % of its infrastructure into Expo City Dubai, setting a new benchmark for how temporary architecture can be visually stunning, environmentally conscious, and future-ready.

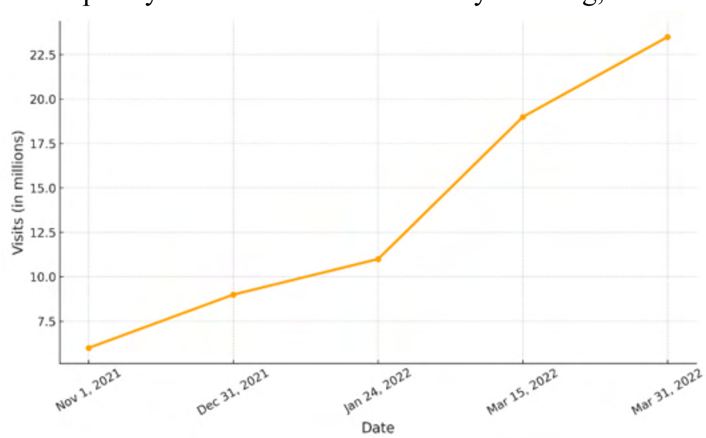

Fig 18. Visitors' profile at Expo

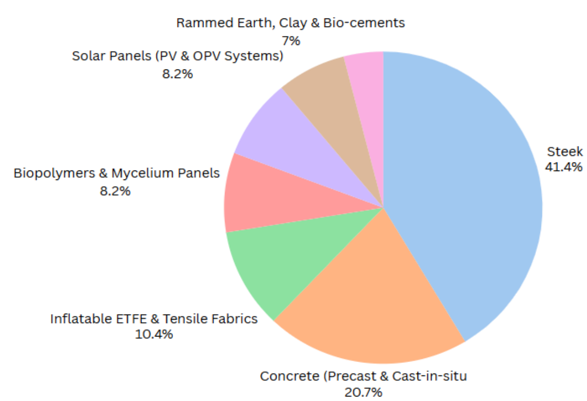

Fig 19. Material usage distribution

Comparative Analysis of Case Studies

Aspect	Mahakumbh Mela	Pushkar Mela	Surajkund Mela	Dubai Expo 2020
Purpose	Religious and spiritual gathering	Cultural fair & camel trading	Promotion of Indian crafts and heritage	International trade, innovation, and cultura diplomacy
Scale	Very large (100+ million visitors)	Large (hundreds of thousands)	Medium (1+ million in 2 weeks)	Global scale (24M+ visitors, 200+ pavilion
Duration	45–60 days (every 1 years per city)	14 days (annually)	15–20 days (annually)	6 months (every 5 years)

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Material Used	Fabric, bamboo, tarpaulin, iron frame	Canvas, bamboo, cloth, wood	Bamboo, cane, mud, thatch	Steel, tensile fabric, high-tech materials
Infra-structure	Massive **temporary city**: roads, tents, sanitation, crowd control tech	**Basic temporary setup**: stalls, animal enclosures, access paths, ghats maintenance	**Semi-permanent** venu fixed layout with temporary pavilions & services	**Smart permanent infrastructure**: metro, digital systems, nation pavilions
Structural Stability	Stable for massive crowds and Weather	Basic, exposed to elements	Moderate, designed for form and function	Engineered to international safety standards
Lifecycle	6-12 months setup + 1-3 months dismantling	1-2 months setup + 15-30 days dismantling	1–2 months setup + 15–30 days dismantling	2–3 years setup + 3–6 months dismantlin
Estimated Material Cost	₹600–800 crore (entire setup), Material share ~₹300–400 crore	₹15–20 crore (Rajasthan Tourism + local traders)Material share ~₹6–8 crore	₹25–30 crore (Haryana Tourism) Material share ~₹10–12 crore	AED 25 billion (₹55,000+ crore) total Material share ~AED 5–7 billion (₹11,000–15,000 crore)
Approx. Quantity Used (Tonnes)	8,000–10,000 tonnes (pontoons, tents, metal poles, toilets, bamboo, tarpaulin)	600–800 tonnes (bamboo, cloth, animal enclosures, stalls)	1,200–1,500 tonnes (wooden kiosks, steel supports, stage infrastructure)	60,000–70,000 tonnes (steel, ETFE, solar panels, textile membranes, plastics)
Reuse & Recycling Practices	70% waste recycled, 90% plasti eliminated, Tents an toilets reused in future events	80% materials reused annually, Temporary bamboo & fabric dismantled & stored	Most stalls reused from previous years, Minima concrete use; high recyclability	80% structures repurposed into **Expo City,** 38,000+ tonnes of plastic recycled, dvanced smart waste systems

Key Insights

- **Fleeting but Meaningful :** Structures represent local rituals, national identity, & spatial memory.
  → *Example: Over 300 temporary akharas at Kumbh Mela are spatial expressions of spiritual and cultural heritage.*
  Importance of Modularity : Prefabricated sanitation units, bamboo pavilions, and mobile clinics allow quick assembly and disassembly.
  → *At Kumbh Mela 2019, over 120,000 toilets were installed in less than a month using modular systems.*
  Integration of Tradition and Technology : The use of GIS mapping at Kumbh, traditional bamboo and tarpaulin at Sonepur, and kinetic facades at Dubai Expo showcases innovation rooted in culture.
  → *Dubai Expo 2020 used smart kinetic facades that responded to heat & light for comfort.*
  Temporary but Purposeful : Event-based zoning, cultural storytelling elements, and spatial hierarchies reflect intentional and thoughtful design.
  → *At Sonepur Mela, zones are designated for religious rituals, livestock trade, and community functions.*
- **Designed for Inclusivity :** Accessible toilets, multilingual signage, and shaded rest zones ensure universal access and user comfort.

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→ *Tactile flooring, audio announcements, and barrier-free ramps are integrated at ISBTs and public events.*

- **Tactical Urban Interventions :** Pilot projects in public spaces help test urban design ideas before permanent implementation.
  → *Raahgiri Days in Gurgaon inspired lasting infrastructure for pedestrian and cyclist safety.*

Conclusion

Fleeting architecture, while temporary in nature, proves to be a powerful and responsive design strategy addressing the dynamic needs of society, culture, and space. As seen in case studies like the Mahakumbh Mela, Pushkar Camel Fair, Surajkund Mela, and Dubai Expo, these structures go beyond basic functionality to embody innovation, inclusivity, and cultural significance. They serve as vessels of **cultural memory and local identity**, constructed with regional materials and rooted in traditional forms. Their **modular and flexible nature** allows quick setup and dismantling—essential for large-scale events with massive, short-term crowds. These examples also highlight a strong shift towards **sustainable practices**, incorporating reuse, efficient material usage, and minimal environmental impact, especially evident in projects like Dubai Expo.

Fleeting architecture further acts as a **tool for experimentation**, enabling the testing of urban strategies and spatial ideas before permanent implementation. It fosters collaboration between designers, authorities, and communities, encouraging participatory design processes. Ultimately, it allows us to reimagine how space, time, and identity can intersect meaningfully—even if only for a moment. With a strong emphasis on **universal accessibility**, features like tactile paths, ramps, and multilingual signage make these environments welcoming to all. In essence, fleeting architecture is not just about temporality—it's about **designing with intent, adaptability, and cultural relevance**. It offers a framework for shaping responsive, inclusive, future-ready spaces reinforcing the belief that **"Change is the rule of the world."**

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ISBN 978-93-342-4408-3

Identifying and Analyzing Architectural Framework of Disaster Resilience for Healthcare Facilities through Resilient Parameters

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Abstract

To ensure that structures will endure and adapt to modern day risk and hazards, developing architectural framework for disaster resilient practices is very crucial in this modern world. Especially hospitals, the critical one needed it the most. Architects need various kinds of frameworks for making buildings not just structurally sound and safe but also capable of convalescing and flourishing after the disastrous event. Incorporating disaster resilient framework, a more resilient and sustainable future for the built environment can be made. Recent studies highlight the need for a roadmap or blueprint for evolving resilient architectural styles especially for critical infrastructure. A precise and detailed architecture framework is needed of the hour that may provide insight into principles and practices for creating and using the resilient architecture description of a resilient building system. And this framework must structure planners' thoughts by dividing the resilient architecture description into fields, stratums or visions, and put forward models having matrices and diagrams for detailing all aspects. **Aim & Objective:** This research aims to analyze the architectural framework for increasing disaster resiliency of hospitals by highlighting resilient parameters and improving contemporary practices, by-laws, codes and policies. **Background:** The increasing frequency and intensity of disasters on global level, existing hazard vulnerability of hospitals, hospital as a lifeline and progression in resilience topics are one of the most dynamic forces that make it deemed necessary. **Gap:** This paper also aims to highlight some missing or underdeveloped research or practice as integrated architecture framework, physical manifestation of policies, functional continuity, capacity building and shortage of architectural driven case studies. **Methods:** A review of academic journals, research reports, books, conference proceedings, case study of disasters, national and international guidelines related to disaster and resilient principles has been done. **Result:** Architectural frameworks are often developed but not regularly updated with time and technological advancements. Frameworks need to be revised on a regular basis. They are trans-disciplinary like management, engineering and architectural domains. **Conclusion:** There is an urgent need for an architectural framework for developing disaster resilience in healthcare facilities, stuck in a systematic identification and analysis of key resilient parameters. Through an in-depth literature review and critical case study analyses, there are future study needed to further highlight that how architectural design decisions, spanning site selection, structural integrity, non-structural systems, and functional spatial planning, collectively contribute to a facility's ability to resist, absorb, adapt, and recover from diverse disaster events.

Keywords: *Architecture framework, internal hospital disasters, resilient parameters*

INTRODUCTION

A planning & design strategy has positive impacts on patient health outcomes in hospitals. [1]. So a hospital must be ready for disaster by means of planning and design strategies. When hospitals aren't ready for disasters, it causes big problems. They struggle to provide regular healthcare, handle emergencies, take care of patients, and even communication between internal departments.[2]. Hospitals' evolving capacities and varying risks, especially in resource-limited and emergency-prone areas, must be factored into operational and evaluation strategies for both routine and emergency times.[3]. In areas of the Indian subcontinent which are prone to natural disasters, building resilient architecture isn't just an option—it's essential.[4]. Our buildings and infrastructure have faced many crises over the last decade, from pandemics and climate disasters to their widespread health impacts. While past research looked at

ISBN 978-93-342-4408-3

single crises, we now need to understand solutions for multiple, interconnected crises to build a more resilient environment.[5]. Disaster preparedness in hospitals is a major concern globally, demanding proactive steps to reduce the harm from natural or human-made disasters. Bodies like India's National Disaster Management Authority are vital in creating these crucial response strategies. This highlights the need for a holistic preparedness strategy that includes well-defined plans, rigorous training, and community participation to guarantee safety during emergencies.[6]. The rise in hospital fires, coupled with varied regional safety protocols, urgently demands tailored and enhanced preparedness strategies for healthcare facilities. Addressing this critical challenge requires a global, collaborative effort to foster safer healthcare environments.[7]. Architects and urban planners, despite their expertise in community-focused spatial design for disaster risk reduction and long-term rebuilding, are rarely engaged in disaster management. A crucial reorientation is needed to integrate core disaster management concepts like vulnerability, urban resilience, climate change adaptation, and risk-based and community planning into design curricula, otherwise its full potential for enhancing resilience won't be met.[8]. Further research is needed to identify other relevant factors and architectural solutions for therapeutic environment capacity building. [9]Architects and their process are crucial for community resilience and sustainability, necessitating regionally tailored architectural frameworks. Architects are uniquely positioned to create people-oriented projects that blend humanitarian values with technical and environmental considerations. Integrating architects' expertise, particularly in "build back better" strategies, will improve disaster response, fostering development that ensures communities thrive post-disaster.[10]

HOSPITAL DISASTERS

Hospitals face a wide spectrum of disasters, categorized broadly as natural, technological, or artificial. Natural disasters (like earthquakes, floods, and severe storms) are uncontrollable events with devastating potential. Technological disasters stem from infrastructure failures, demanding swift action to restore operations. Artificial disasters, caused by human action or negligence, necessitate robust safety protocols and risk management. Disasters can also be classified by origin: internal (e.g., fire, hazardous material spills, bomb threats, power outages, equipment failures) or external (e.g., natural phenomena like pandemics or human-made events like terrorist attacks and industrial accidents). Other specific threats include tornadoes, hurricanes, transportation incidents, chemical/radiation leaks, loss of essential utilities (water, medical gases, and telecommunications), staff access issues, and elevator emergencies.[11]

HOSPITAL AS CRITICAL INFRASTRUCTURE & RESILIENCE

Hospitals are critical infrastructure due to their essential role in community well-being, public health, and emergency response. Their failure during any disaster profoundly impacts human life and societal stability, as they serve as frontline crisis responders requiring continuous operation for life-saving interventions and recovery. Thus, resilient hospital infrastructure is a fundamental necessity, achieved by integrating resilient architectural parameters into comprehensive architectural frameworks. Ultimately, this holistic architectural approach ensures the functional continuity of healthcare services, significantly strengthening community resilience. (*Aghababian, Lewis-1994)*

ARCHITECTURAL FRAMEWORKS

The architectural framework for disaster resilience in healthcare facilities, identified and analyzed here, underscores a critical shift from mere hazard resistance to a holistic, integrated approach to design. Below, 11 architectural frameworks have been discussed with their resilient features in Table 1.

S. No	FRAMEWORK	CONCEPT	ARCHITECTURAL APPLICATION
1.	WHO/PAHO Hospitals Safe from Disaster Initiative.12	This initiative, particularly through its "Hospital Safety Index" and "Smart Hospitals" project functions as a de facto framework. It	o Site Selection Structural Safety o Non-structural Element Protection o Basic Services Resilience o Access and Egress

ISBN 978-93-342-4408-3

		emphasizes a comprehensive, multi-hazard approach to hospital safety and resilience.	o Functional Design
2.	Critical Infrastructure Protection (CIP) Frameworks (e.g., DHS/FEMA in the US).	While broad, these government-level frameworks define critical infrastructure sectors (including healthcare) and provide guidance on protecting them from various threats	o Informs site hardening o physical security measures o blast resistance o integration with broader community emergency plans
3.	ASCE/SEI 7:Minimum Design Loads & Associated Criteria for buildings & Other Structures (Performance -Based Design). [14]	While a standard, ASCE 7 effectively acts as an engineering-architectural framework by providing minimum load requirements and increasingly, performance-based design (PBD) criteria.	o Seismic Performance Levels o Wind Pressure Resistance o Snow and Other Loads o Robustness of Connections
4.	International Building Code (IBC) and NFPA 101 (Life Safety Code) - Applied to Healthcare. [15]	These are foundational building codes and life safety standards that, when applied specifically to health care facilities (often with special hospital chapters), form a regulatory framework for basic resilience. They focus heavily on life safety, fire protection, and safe egress.	o Fire Compartmentation o Egress Systems o Emergency Lighting o Hazardous Material Storage o Accessibility for Emergency Responders
5.	Academic/Research-Proposed Resilience Frameworks. [16]	These conceptual frameworks that go beyond codes to include emergent properties like adaptability and resourcefulness as explicit design goals. These frameworks argue for a more holistic, future-proof approach to hospital design.	o Flexible and Modular Design o Scalable Utilities o Passive Survivability o Distributed Systems o On-site Resources
6.	EnhancedArchitectural Design(Crime Prevention Through Environmental Design–CPTED).17	Integrates security considerations into the initial architectural design process to deter, detect, and delay malicious acts (relevant for artificial disasters).	Strategic placement of entries/exits, clear sightlines, controlled access points, hardened facades, integrated surveillance systems, and designing vehicle barriers.
7.	Passive Survivability Design. [18]	Focuses on designing buildings to maintain habitable conditions (temperature, light, ventilation) for occupants even when active systems (electricity, HVAC) are unavailable due to a long-term power outage or other disruption.	Maximizing natural ventilation strategies, incorporating thermal mass, optimized window placement for daylighting, shading devices, and robust building envelopes
8.	Eco-Districts / Resilient community frameworks (e.g., LEED for Cities and Communities, Envision). [19]	While broader than individual buildings, these frameworks provide guidelines for designing and developing entire neighborhoods or communities that are sustainable and resilient.	Influences the design of individual buildings within the context of community-wide resilience strategies, such as shared decentralized utilities, interconnected open spaces.

ISBN 978-93-342-4408-3

9.	"Build Back Better" Principles[20]	A guiding principle in post-disaster reconstruction that advocates for not just rebuilding what was lost, but.improving it to be more resilient	Directly influences architectural design decisions in reconstruction projects, promoting the adoption of resilient materials.
10.	Adaptability and Flexibility Frameworks. [21]	Emphasizes the building's capacity to adjust its configuration, function, or capacity in response to changing conditions, future threats, or evolving needs. This is particularly crucial for long-term resilience and unpredictable events like pandemics.	Flexible layouts, modular components, and designs that allow for easy repurposing of spaces (e.g., converting patient rooms to ICU units, or offices to temporary wards).
11.	Performance-Based Design (PBD) Frameworks. [22]	Focuses on achieving specific, measurable performance objectives (e.g., "immediate occupancy," "life safety," "collapses prevention") for a building during and after a hazard event, rather than just meeting prescriptive code minimums.	Dictates design choices for structural systems, connections, non-structural elements, and even material selection to ensure the building performs as intended under various loads.

Table 1 : Architectural Frameworks

RESILIENT PARAMETERS

Hospital buildings are incredibly complex structures that must cater to a wide range of needs, from highly specialized medical functions to the emotional well-being of patients and staff.[9][1]Their architectural parameters go far beyond just aesthetics or basic functionality. Here are 16 key architectural parameters identified and analyzed in Figure 2 for hospital buildings.

S. No	ARCHITECTURAL PARAMETER	DEFINITION	RESILIENT CHARACTERISTICS
1.	Site Selection and Planning	Proximity to population, accessibility, natural hazards assessment, expansion potential and environmental impact.	Natural Hazards Assessment, Proximity to Population, Expansion Potential.
2.	Zoning and Functional Layout	Clear segregation of public, semi-restricted, restricted (sterile), and service zones to manage traffic flow, minimize cross-contamination.	Hazard Containment/Isolation, Core Services Protection (Robustness), Decontamination Zones, Flexible Zoning
3.	Circulation and Wayfinding	Efficient and clear pathways for patients, visitors, staff, and materials (clean vs. dirty flows) with intuitive signage and minimal travel distances.	Redundant Egress Paths, Segregated Flows (Infection Control), Emergency Vehicle Access, Resilient Way finding
4.	Infection Control	Design features that reduce pathogen transmission, including easily cleanable surfaces, appropriate ventilation systems	Adaptable Ventilation Systems, Durable, Cleanable Surfaces, Decentralized Hand Hygiene
5.	Flexibility and Adaptability	Designing spaces that can be easily reconfigured or expanded to accommodate changing medical needs, technological advancements, or surge capacity during	Modular Planning: Generic/Universal Rooms: Scalable Infrastructure Non-Load-Bearing Partitions:

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		emergencies (e.g, modular planning, generic room sizes).	
6.	Safety and Security	Comprehensive measures for patient and staff safety, including fire safety systems (compartmentation, egress).	Fire Compartmentation: Hardened Entrances/Perimeter:
7.	Sustainability & Environmental Impact	Incorporating energy-efficient systems (HVAC, lighting), water conservation (rainwater harvesting)	Renewable Energy, Rainwater Harvesting/Greywater Recycling, High-Performance Envelope
8.	Technological Integration	Planning for current and future medical technologies, IT infrastructure (high-speed data, telehealth capabilities), and smart building systems (BMS, automation).	Redundant IT Infrastructure, Resilient Communication Systems, Smart Building Management Systems (BMS), Telehealth Infrastructure:
9.	Accessibility and Inclusivity	Ensuring universal access for all individuals, regardless of physical abilities, through ramps, wide corridors, accessible restrooms, and clear navigation for patients	Elevator Redundancy/Manual Override Accessible Restrooms/Facilities
10.	Acoustics and Noise Control:	Implementing design strategies (sound-absorbing materials, quiet zones	Sound-Absorbing Materials: Strategic Adjacencies:
11.	Material Selection	Choosing durable, non-toxic, easily maintainable, and appropriate materials for each functional area, considering infection control, aesthetics, and long-term costs.	Durable and Impact-Resistant Materials, Non-Toxic and Low-VOC Materials, Easily Repairable/Replaceable Materials
12.	Structural Integrity	Designing the building's core structure to withstand anticipated loads, including dead, live, wind, and seismic forces, ensuring stability and safety.	Seismic Design: Wind Resistance: Flood Resistance Progressive Collapse Resistance
13.	Mechanical, Electrical, and Plumbing (MEP) Integration	Efficient layout and coordination of complex HVAC, electrical distribution, plumbing, medical gas, and waste management systems, often with redundancy.	Decentralized MEP Systems: Hardened MEP Infrastructure: Redundant Systems: Emergency Power Generation: Potable and Non-Potable Water Storage:
14.	Vertical Circulation	Strategic placement and adequate sizing of elevators and staircases for efficient movement of patients	Dedicated Emergency Elevators Protected Stairways Ramps
15.	Facade Design	Aesthetic appeal, patient comfort (e.g., glare control), energy performance (insulation, shading), and potential for natural ventilation.	Impact Resistance Thermal Performance Shading Devices Natural Ventilation Openings
16.	Future Proofing/ Expandability	Designing the overall master plan and individual building components with the foresight for future expansion, renovation, or adaptation without significant disruption to ongoing operations.	Resilient Features (Core Adaptability) Master Plan Flexibility: Over-designed Foundations/Structures: Open-Ended Utility Systems:

Table 2 : Architectural Frameworks

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RESULTS & DISCUSSIONS

Our analysis, drawing from an extensive literature review, case studies of post-disaster healthcare facility performance, and expert interviews, has led to the identification of architectural frameworks and parameters for disaster resilience in healthcare facilities. The identified and analyzed 11 architectural frameworks and 16 architectural parameters with their resilient characteristics demonstrate that true architectural resilience in healthcare facilities is not achieved through isolated interventions but through the synergistic application of evolving and new architectural advancement. The identified architectural framework holds significant implications for various stakeholders involved in healthcare infrastructure development as Architects and Designers, Hospital Administrators and Owners and Policymakers and Regulators: Our findings suggest a need for evolving building codes and healthcare facility regulations to explicitly incorporate these comprehensive resilience parameters. Each parameter may be further broken down into specific architectural design considerations and for future research. The identified framework and architectural parameters with resistant attributes of each parameter need interdependencies and constant evolution with a regional context. It also demonstrates that a truly resilient healthcare facility requires an integrated design approach where these three parameters are not treated in isolation but as interdependent components.

CONCLUSIONS

Our findings underscore that effective disaster resilience in the built environment of healthcare is not a singular design feature but a multifaceted outcome of integrating these interlinked architectural considerations throughout the entire lifecycle of a facility, from planning and design to construction and operation. There is a huge list of resilient parameters which can play a very critical role if properly designed against specific disaster. The highlighted frameworks and resilient parameters provide architects, urban planners, hospital administrators, and policymakers with a systematic approach to evaluating, designing, and retrofitting healthcare facilities to withstand and recover from diverse crises. By moving beyond traditional single-hazard resistance and embracing a holistic perspective that includes adaptability and resourcefulness, healthcare facilities can enhance their capacity to maintain essential services, protect lives, and contribute to the broader recovery of communities in the face of escalating global threats. Future research should focus on developing quantitative metrics for these parameters and exploring the socio-economic benefits of such resilient investments.

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ISBN 978-93-342-4408-3

Review of Building Materials used to Improve the Life of Existing Concrete Structures Decayed Due To Dampness

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Abstract:

This paper presents a comprehensive review and analysis of smart materials used to improve the life of existing concrete structures. Basically, when we prepare concrete for a particular structure, we mainly focus on the grade of the concrete, standard conditions of location, characteristic compressive stress, and properties of the concrete in plastic and hard states. In the design mix, we decide the quantity of required water, fine aggregate, coarse aggregate, and admixtures. In this procedure of preparing concrete, we never consider the changes that may be faced by the concrete structure during its design life. Practically, there are so many factors that affect the life of concrete, like, Dampness, variations in temperature, unexpected extra loads, seismic activities, flooding, etc. Generally, structures will face different types of challenges, and due to this, concrete structures will face problems. Concrete structures show cracks, rusting of reinforcement, decay of concrete, etc. At an early age, before the expected time. Because of this, our structure is not good in terms of serviceability and durability. The reason behind this is that we never consider the practical factors that affect the life of concrete structures during concrete preparation. We also know that if a structure is showing early indications of failure, in this case, retrofitting or restoring may not work.

Basically, this research work is a sequence of my previous research paper, in that it is concluded that, we have different building materials to improve life of concrete in case of new structures.so, In this work we perform a live case study on a 20-year-old Apartment building.

In this research, we focus on different practical problems that may be faced by concrete structures, and due to this, the life of the structure is reduced. In this work, we consider all the research papers that give solutions to overcome the problem of early-age concrete failure by using different smart materials added during the preparation of concrete.Basically, we focus on how to use them in our practical problems. We recommend some situations where we can use the latest solutions for different types of problems that increase the life of concrete.

The aim of this work is to find sustainable and economic building material that can improve the life of existing concrete structures facing the problem of deterioration at an early age due to dampness.

Key Words: *Existing concrete structures, life of concrete, serviceability, durability.*

Introduction:

In this work we focus on one of the biggest factors that is responsible for the early decay of existing structures: dampness. Dampness is one of the biggest problems that is faced by so many existing structures due to this structural member decay at an early age and losing their load-bearing capacity. Structural dampness is defined as the unwanted moisture that is present in part of the structure. Dampness can occur in structures in different ways, like natural and artificial ways. Natural dampness may occur due to seepage of rainwater from the outside environment or due to condensation within the structure. Artificial (man-made) dampness is caused by an improper water drainage system; due to the uneven slope, water cannot drain out in the right direction.

Dampness can be observed easily in the initial phase, but when it is not cured on time, it will cause serious structural failure. Structures that have dampness issues are losing their strength as time passes. When an earthquake or cyclone comes, the weak structure will fall down easily. Waterproofing will work for new structures because, in this case, the inner structure is safe and able to bear a load. In this work we

ISBN 978-93-342-4408-3

focus on existing structures that have completed 20 years of service and have the problem of an improper drainage system causing the problem of dampness.

Dampness in structures is one of the serious issues at present time, due to which structures will deteriorate and lose their load-bearing capacity. In this work we focus on some sustainable building material, steel fiber-reinforced concrete (SFRC), that can be used in the retrofitting of structures facing dampness.

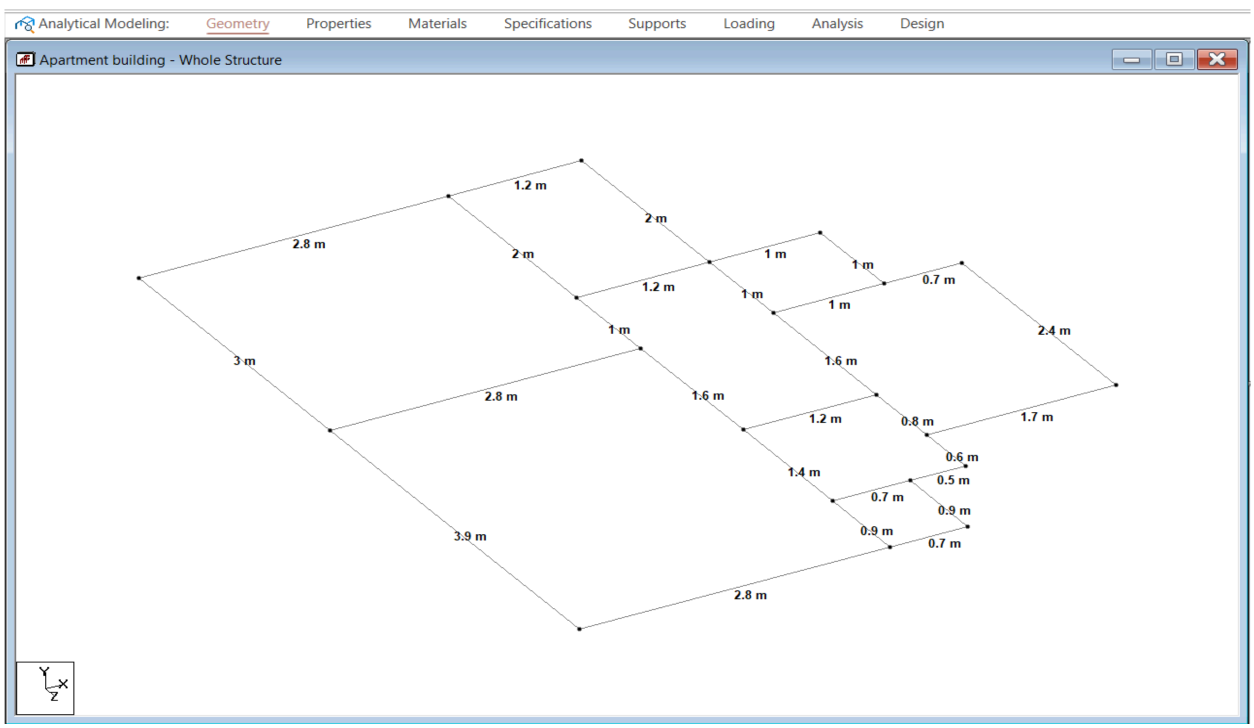
Literature Review:

In this work we have studied and observed different recent research papers. On the basis of their experiments and results, it is clear that the structural members of the existing structure are decayed and losing their strength when they come in contact with moisture/dampness. So, if dampness in structural members is not treated on time, the existing building will fail. All research papers mentioned as references are considered in the review analysis.

Live Case Study:

In this work we are performing a live case study at Sunview Apartment, sec 11 Dwarka, New Delhi. On the basis of visual inspection done while preparing this research paper, it is observed that most of the structural members of the building are facing the problem of dampness. Construction work on this apartment was completed in the year 2000 and open for occupancy. After 20+ years, it is observed that this apartment's structural members decayed and lost load-bearing capacity.

As per observations, the dampness is found due to water leakage from the water drainage system. The water drainage system has been used for a long time, so the pipes got rusted. Some uneven slopes are also seen at roofs due to this rainwater not flowing in the right direction.



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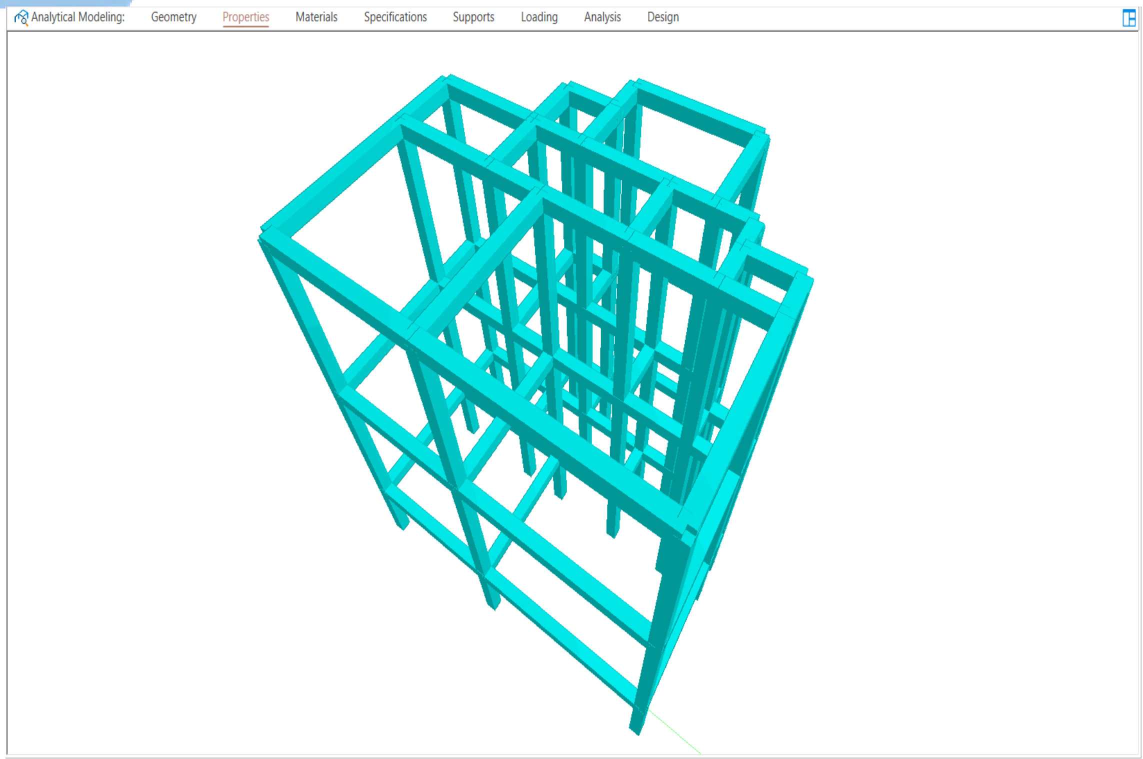

Image 1 & 2 : Plan view and 3D Analytical Model of apartment building (Software courtesy: STAAD Pro)

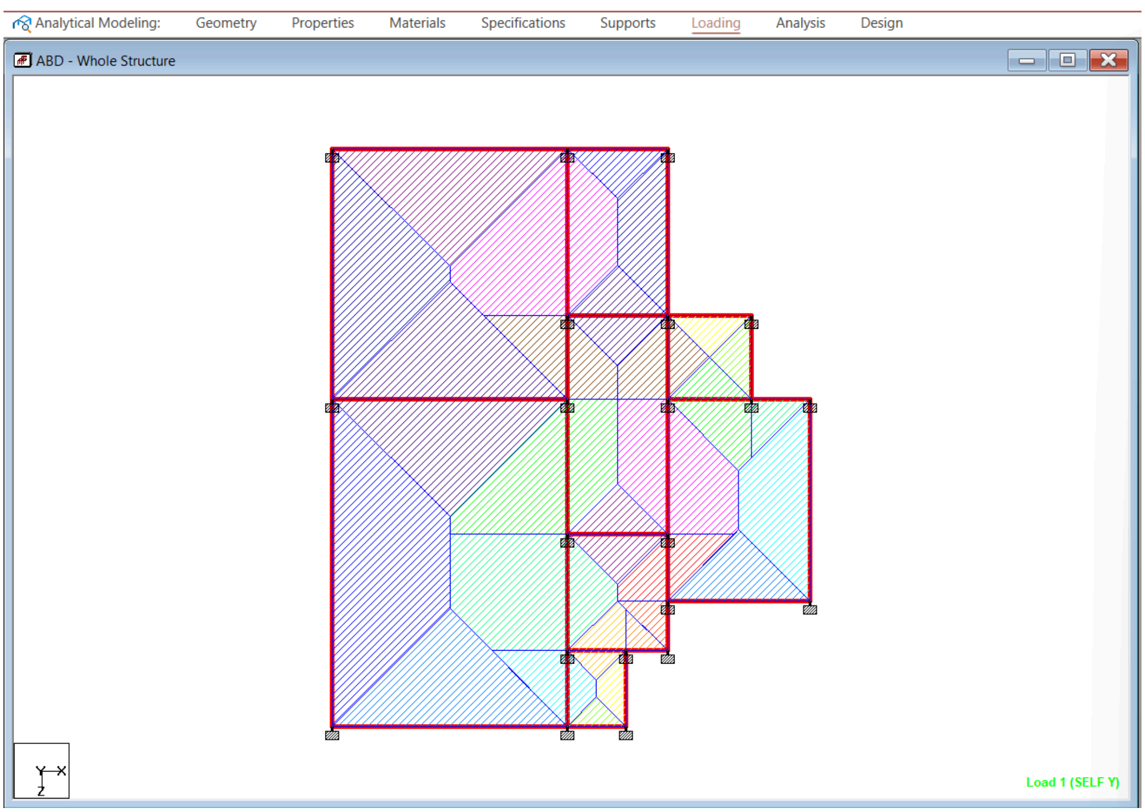

Image 3 : Structural members subjected to loads in top view (Software courtesy : STAAD Pro)

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On the basis of observations, we can classify the Dampness of structural members.

a) <u>MILD DAMPNESS</u> - It is the initial phase of dampness. In this, it is observed that the leakage just started a few months ago; due to this, the ceiling and wall plaster look swollen and decayed. In this case, the new existing structure can be treated by scraping out the decayed surface and covering that structural member with plaster mixed with waterproofing material.

Image 4 : Showing mild damage to the outer wall at the water drainage system joint. (Image Credits : Author)

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Image 5 & 6 : Showing mild decay of outer walls due to leakage at drainage pipes. (Image Credits : Author)

b) <u>MODERATE DAMPNESS</u> - In this phase of dampness, the moisture can be seen across the structural member, or we can say that the moisture transferred from one floor to another floor. In this condition we can observe the decayed structural members like beams, columns, and slabs, mostly in the superstructure of the existing building. In this case, first we have to scrape out all the decayed layers, know the source of dampness, and assess the extent of the damage. This type of dampness is caused by failure of the water drainage system, constant leakage of water, or it can be due to uneven flow of rainfall water. In this case we can also see some minor cracks due to uneven settlement of the wall. Sometimes the source of dampness is not in our floor/flat; it can be your side floor/flat. In this case, after knowing the extent of the damage, the type of retrofitting can be decided. It depends on the condition; we want to use local retrofitting or global retrofitting.

Image 7 : Showing moderate decay of slab due to overflow of water tank and improper drainage slope. (Image Credits : Author)

ISBN 978-93-342-4408-3

Image 8 : Showing Moderate decay of outer parapet walls due to rain water. (Image Credits: Author)

c) SEVERE DAMPNESS – In this phase of dampness, it occurs again and again. After some days of treatment, we can see the dampness of the structural member is increasing. This type of dampness can be seen when we treated the decayed structural member without knowing the source of dampness. Another condition is that the treatment of decayed structural members is done with non-durable or cheap building material. Sometimes dampness can be coming from the foundation from the substructure. In this case we have to examine the extent of damage. In some cases, major cracks may be seen due to temperature differences. In this condition, non-destructive testing is also performed to ensure that the structural member has the required strength. In this phase of dampness due to severity, we need to make a decision on whether retrofitting is to be done or not on the basis of performance analysis of the building. And we have to use a durable, serviceable building material having all the required properties so that it can retain moisture. Practically, it is observed that, in this phase, the structural member not only looks decayed but is also losing their load-bearing capacity.

Image 9 : Showing severe damage to the connecting beam. (Image Credits: Author)

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Image 10 : Showing severe decay outside of the kitchen wall near the water drainage system.

Image 11 : Showing Severe Damage to the column due to this reinforcement got corroded.

Image 12 : Showing severe damage at outer walls of building due leakage of water drainage system. (Image credits: Author)

ISBN 978-93-342-4408-3

In this work we consider different building materials that have all the required properties to use as retrofitting material that is durable and sustainable.

REVIEW ANALYSIS: -

BUILDING MATERIAL	PROPERTIES
Steel Fiber Reinforced Concrete:- (SFRC)	Steel fibre reinforced concrete is advanced building material containing all required properties for a retrofitting material used at damp places. As per study and experiments of recent research papers. It is observed that SFRC has the following properties. (i)Property of water resisting. Properties show durability of building material. (ii)Improving bond strength between concrete and reinforcement shows serviceability as better strength. (iii)Improved Ductility of structure shows better load bearing capacity and resistance against dynamic loading and cracking. (iv)Economic retrofitting building material as compared to conventional concrete. It can be used in moderate/severe damp structures.
Glass Fiber Reinforced concrete:- (GFRP)	Glass fibre reinforced polymer wraps is advanced building material containing all required properties for treatment of mild damp decayed structures. As per study and experiments of recent research papers it is observed that GFRP has following properties. (i)good in resisting corrosion in structures. (ii) Improves the load bearing capacity of structures. (iii) Improves response of structures against dynamic loading. It can be used in mild/moderate damp structures.
Epoxy Resin grouting	Due to the temperature difference between a damp side (lower temperature side) and outer surface exposed to the Sun (high temperature), expansion and contraction occurs because of this action cracks will appear. Epoxy grouting is the right way to treat such damp decay structural members.it can be used for repair and maintenance of historical monuments. As per study and experiments of recent research papers it is observed that epoxy grouting has following properties. (i) It is helpful to recover the strength of structural members. (ii) It can be used in damp places shows durable after treatment. (iii) This treatment of damp structures is low cost. It can be used for minor cracks and initial phase of dampness in structures.

ISBN 978-93-342-4408-3

CONCLUSION: -

People using buildings for different functions, when these structures are serving for the long term, need repair and maintenance on time. In case people avoid on-time maintenance and repair of buildings constantly, due to this the building starts to decay and lose the strength of existing structures. In case of new building construction, appropriate supervision is required because a lack of supervision will create structural defects like an erroneous slope in the water drainage system. Sometimes dampness is a reflection of our purposeful functions to live in a building. If the treatment of a decayed structural member is done in the initial phase, then it costs less, and if this treatment is done after a long time, then it takes time and extra prices for repair and maintenance. From a structural engineering perspective, due to decay and cracks, structural members are not serviceable and durable. Structurally, any structure facing a dampness issue is not only reducing life but also creating weak points in structures. Because of this, a structure may fall at any time. In this review analysis, it is observed that on the basis of the extent of decay and damage, we can classify the condition as mild, moderate, or severe. After visual inspection, we select the course of action. In this sequence, we require a smart building material that is durable, serviceable, and strong and can serve the purpose. We recommend the above smart material on the basis of review analysis.

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ISBN 978-93-342-4408-3

Computational Design Evolution: Applications of Simulation and Digital Twin Technologies in Architecture

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Abstract:

The rapid expansion of digital technology has dramatically altered architectural practice, notably with the incorporation of simulation-driven design and digital twin technologies. This study looks into how these tools influence current design decisions, improve building efficiency, and shape the future of sustainable and intelligent architecture. Simulation-driven design allows architects to visualize, test, and optimize building systems using computational modelling prior to physical construction, allowing for more data-driven decisions. Meanwhile, digital twin technology generates real-time, dynamic reproductions of physical structures, enabling for continuous monitoring, predictive maintenance, and adaptive design responses throughout an operational life of a building.

The paper presents a comparative overview of widely used tools such as EnergyPlus, Radiance, OpenFOAM, DesignBuilder, Ladybug, and digital twin platforms like Autodesk Tandem, Bentley iTwin, CityZenith SmartWorldPro, Willow Twin, ESRI ArcGIS Urban, Siemens Digital Twin, etc. It evaluates these tools based on their techniques, applications, benefits, and limitations. The analysis is supported by multiple global case studies that illustrate successful implementations of both simulation tools and digital twins in diverse architectural contexts.

Challenges such as high learning curves, data management issues, integration complexity, and high initial costs are critically discussed. The study also explores future directions, emphasizing the potential of integrating artificial intelligence, machine learning, and IoT for greater adaptability and automation in architectural design and operations.

The findings show that, despite remaining constraints, simulation and digital twin technologies are critical enablers of architectural innovation, performance improvement, and sustainability. The report finishes by proposing for expanded use of these tools, backed up by research, education, and industry collaboration to create smarter and more resilient built environments.

Keywords: Simulation-Driven Design, Digital Twin Technology, Building Performance Simulation, Design Optimization

1. INTRODUCTION

Integrating digital technologies into design and construction processes has resulted in a considerable shift in the architectural field. Traditionally, architectural design was primarily an intuitive and artistic endeavour; however, as the complexity of modern building requirements, ranging from energy efficiency to user-centric spaces, has increased, so has the reliance on data-driven decision-making tools [1]. Among these breakthroughs, simulation-driven design and digital twin technologies have emerged as crucial factors changing architectural practice.

Simulation-driven design is a technique in which computational models simulate various building performance characteristics such as thermal behaviour, daylighting, and structural efficiency, allowing architects to forecast and optimize results from the early design phases [2]. Meanwhile, Digital Twin

ISBN 978-93-342-4408-3

Technology (DTT), which was created for the manufacturing and aerospace industries, is gradually being applied to the built environment. A digital twin is a dynamic, virtual counterpart of a physical asset, system, or city that is constantly updated with real-time data, allowing for continual monitoring, simulation, and improvement [3]. When integrated into architectural workflows, digital twins provide an effective platform for optimizing building performance, lifecycle management, and user experience [4].

The significance of using these technologies has been heightened by critical global concerns. Urbanization, climate change, and the demand for sustainable built environments require architects to create smarter, more adaptable structures. The capacity to virtually prototype and optimize design decisions before physical construction reduces resource consumption, operational costs, and increases occupant satisfaction [5]. Furthermore, the combination of Internet of Things (IoT) devices, Building Information Modelling (BIM), Artificial Intelligence (AI), and cloud computing with digital twins provides architects with new insights into the performance and evolution of their projects [4]. Despite its enormous promise, the use of digital twins in architecture is not without obstacles. High implementation costs, interoperability challenges, data security concerns, and a steep learning curve are all significant hurdles [6]. However, advances in computational methods, open data standards, and collaborative digital platforms are gradually making these technologies available to architects and urban planners.

This article investigates the role of simulation-driven design in architecture using digital twin technologies. It aims to identify regularly used digital tools, compare their functions and challenges, investigate their use through case studies, and critically assess their implications for the future of architectural practice. Through this discussion, the paper positions digital twin technologies not merely as supportive tools but as transformative agents in designing resilient, sustainable, and intelligent built environments.

2. UNDERSTANDING SIMULATION-DRIVEN DESIGN AND DIGITAL TWIN TECHNOLOGY

The gradual usage of computational design tools has characterized the transition of architecture from manual drafting to digital modeling. The concept of simulation-driven design is central to this transition, since it allows architects to forecast building performance, environmental interactions, and user experiences before construction begins [2]. Simulation-driven design incorporates environmental research, structural optimization, and energy modeling, resulting in more informed and sustainable design decisions. Early-stage simulations provide essential feedback loops, encouraging an iterative process that balances aesthetics, functionality, and environmental responsibility [7].

Architectural simulation technologies include thermal comfort analysis, daylight simulations, Computational Fluid Dynamics (CFD) for ventilation investigations, and structural resilience simulations. Tools like EnergyPlus, Radiance, and OpenFOAM have allowed architects to simulate and adapt their ideas in response to complicated performance indicators. This method significantly transforms design from intuition-driven to evidence-based, encouraging a culture of predictive analysis rather than reactive troubleshooting [8].

Parallel to the advent of simulation-driven design comes the emergence of Digital Twin Technology (DTT). A digital twin is a virtual counterpart of a physical asset, system, or environment that is continuously updated with data from sensors, IoT devices, and other digital sources [4]. Originally developed for the manufacturing and aerospace industries, digital twins in the architectural realm depict entire buildings, campuses, or even cities, providing dynamic models that progress alongside their actual counterparts [9].

A digital twin's architecture typically consists of three major components: the physical asset (such as a building), the virtual model (the digital twin), and the data connection between the two [3]. This connection continuously mirrors and analyses real-world variables such as energy usage, temperature variations, occupancy patterns, and structural movements. This real-time feedback allows architects, engineers, and facility managers to optimize performance, anticipate maintenance needs, and improve user experiences throughout the building's lifecycle [4].

Furthermore, the combination of Building Information Modeling (BIM) with digital twins has greatly increased their potential. While BIM provides static, design-time information models, digital twins expand on this concept by including real-time operational data and predictive analytics capabilities [6]. Advanced digital twins may mimic scenarios like emergency evacuations, system breakdowns, and energy-saving methods, giving architects a proactive way to manage building performance.

The transition to cognitive twins, which use artificial intelligence (AI) and machine learning algorithms to learn, predict, and recommend optimizations autonomously, is a noteworthy advance in digital twin evolution [10]. Such capabilities elevate digital twins beyond reflective tools to active participants in the ongoing management and growth of architectural settings. To summarize, simulation-driven design and digital twin technologies are combining to build a powerful architectural paradigm. They facilitate the transition from static design methods to dynamic, life-cycle-informed techniques that prioritize continual optimization, user-centric adaptation, and long-term stewardship of the built environment. Understanding these technologies is critical for architects who want to innovate in an increasingly data-rich, performance-driven world.

3. OVERVIEW AND COMPARATIVE ANALYSIS OF COMMON SIMULATION AND DIGITAL TWIN TOOLS IN ARCHITECTURE

Simulation tools and digital twin platforms have become crucial components of contemporary architectural practice. They enable data-driven, performance-oriented design decisions, assisting architects in predicting how a building will function in real-world scenarios. This section discusses two types of tools: simulation tools, which focus on studying building elements during the design phase, and digital twin tools, which continue to interact with the building after occupancy.

3.1 Common Simulation tools in Architecture

Simulation tools often concentrate on certain characteristics such as energy efficiency, lighting, acoustics, and airflow. Some of the most commonly used tools are:

- OpenFOAM is an open-source CFD program for studying airflow, ventilation, and indoor air quality in complicated settings [11]
- EnergyPlus, developed by the US Department of Energy, mimics energy and water consumption in buildings. It allows users to accurately model HVAC systems, lighting, and occupant behaviour [12].
- DesignBuilder, based on the EnergyPlus engine, offers a user-friendly interface for energy simulations, daylight analysis, and computational fluid dynamics in a single platform [12].
- Radiance simulates natural and artificial lighting to maximize daylight utilization and visual comfort [13].
- Ladybug Tools, an open-source environmental plugin for Rhino and Grasshopper, enables architects to undertake climate analysis, sun radiation studies, and energy modeling [14].

These technologies help architects make early-stage design decisions by providing predicted information, allowing them to refine their designs iteratively for greater sustainability and efficiency.

3.2 Common Digital Twin tools in Architecture

While simulation tools aim to forecast, digital twin technologies create an evolving real-time link between the physical and digital domains. Some of the leading platforms are:

- Autodesk Tandem is a BIM-based digital twin platform that manages asset information throughout a building's lifecycle. It focuses on producing operational twins straight from design models [15].
- Bentley iTwin is a versatile platform for producing infrastructure digital twins that integrates with engineering workflows and provides real-time performance monitoring [16].

- CityZenith SmartWorldPro is an urban-scale digital twin platform that simulates city infrastructure, energy management, and resilience planning [17].
- WillowTwin, designed for smart building and infrastructure management, provides real-time spatial analytics, energy tracking, and operational optimization [18].
- Siemens Digital Twin for Buildings blends IoT, BIM, and cloud computing to improve facility management [19].
- ESRI ArcGIS Urban, a GIS-based modelling platform, offers city-scale 3D representations for urban planning and simulation [20].
  Each of these platforms provides varied levels of data integration, visualization capabilities, and lifecycle support, influencing how architects interact with their designs after construction.

3.3 Comparative Analysis of simulation and Digital Twin tools

Below is a comparative summary based on the **techniques used, primary benefits, and key challenges**:

Tool	Techniques Used	Primary Benefits	Key Challenges
EnergyPlus	Energy simulation, thermal modeling	Accurate energy modeling, HVAC analysis	Steep learning curve; requires scripting
Radiance	Light simulation, ray tracing	High-fidelity daylight and lighting simulation	Complex setup, computation-heavy
OpenFOAM	CFD simulation, airflow modeling	Advanced airflow analysis, customizability	Requires strong technical expertise
DesignBuilder	Energy modeling, daylight, CFD	Integrated performance modeling, user-friendly	Licensing costs, some limitations in customization
Ladybug Tools	Climate analysis, parametric modeling	Flexibility, integration with design tools like Rhino/Grasshopper	Dependent on other platforms, moderate learning curve
Autodesk Tandem	BIM-based digital twin, data visualization	Smooth transition from BIM to operational twin	Still evolving, limited third-party integrations
Bentley iTwin	Real-time infrastructure twin, sensor integration	Scalable, multidisciplinary project support	High implementation cost
CityZenith SmartWorldPro	Urban twin, IoT integration	Comprehensive urban modeling, sustainability insights	Expensive, high system requirements
WillowTwin	Spatial analytics, energy management	Focus on smart building optimization	Relatively new; scalability issues for small projects

ISBN 978-93-342-4408-3

Siemens Digital Twin	IoT integration, AI analytics	Robust for facility management, strong IoT integration	High initial investment, complexity
ESRI ArcGIS Urban	GIS-based 3D modeling	Ideal for city planning and zoning	Limited in building-specific simulations

3.4 Key Observations

- Simulation tools use physics to anticipate pre-construction outcomes, while digital twin platforms use IoT and AI for real-time post-construction analysis.
- Complementary benefits: Simulation tools improve original designs, while digital twins optimize buildings over time.
- Challenges Reflect Maturity: Simulation tools are more mature after decades of development, whereas digital twin systems are constantly emerging, necessitating significant expenditures and sophisticated IT infrastructure.
- Integration issues exist for both sets of technologies, making interoperability critical. A recurring challenge is the smooth interchange of data between BIM models, IoT devices, and digital platforms [6].
- As architecture shifts to smart, resilient, and sustainable paradigms, the integration of simulation tools during design and digital twins during operation will become more fluid. Mastery of both domains is essential for future-oriented architectural practice.

4. APPLICATIONS OF SIMULATION AND DIGITAL TWINS IN ARCHITECTURAL PRACTICE AND THEIR ADVANTAGES

The use of simulation technology and digital twin systems in architecture has grown dramatically over the last decade, transforming how buildings are planned, managed, and maintained. These technologies enable architects to increase sustainability, optimize building performance, improve occupant comfort, and better manage assets throughout a building's lifecycle.

4.1 Advantages of simulation applications in architectural practice

Simulation tools are most commonly used throughout the early to mid-design stages. They enable predictive modeling across several performance indicators, resulting in better informed and optimal decision-making.

- Architects can use energy modelling programs like EnergyPlus and DesignBuilder to estimate and reduce a building's energy usage, promoting energy efficiency and environmental sustainability. Architects can help achieve net-zero energy targets by simulating various HVAC setups, insulation systems, and building orientations [7], [12]. Early design-phase simulations lower the cost of sustainability solutions by reducing the requirement for retrofitting.
- Modeling the impact of natural light on interior spaces using tools like Radiance and Ladybug. Architects can combine energy savings with occupant comfort by optimizing window placement, shading devices, and material reflectivity [14].
- Optimize thermal comfort and airflow. CFD technologies such as OpenFOAM provide extensive investigation of internal airflows, which aids in the development of natural ventilation techniques and HVAC systems. Properly built airflow systems are critical for occupant health, particularly in the post-COVID age, when indoor air quality has become a primary focus [8].
- Structural Integrity and Safety Simulations: Structural simulations help identify potential vulnerabilities under different loads, such as seismic, wind, and gravity forces. Such simulations are commonly conducted using tools such as ETABS and SAP2000, which ensure compliance with local building regulations and standards [21].

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The use of simulation not only improves building performance, but it also promotes evidence-based design methods that combine intuition with analytical rigor.

4.2 Advantages of Digital Twin applications in architecture practice

Beyond the design phase, digital twin technology brings architectural influence into the operational and post-occupancy stages, providing dynamic building management solutions.

- **Building Operations and Facility Management**: Digital twins, like Bentley iTwin or Siemens' Digital Building Twin, enable real-time monitoring of building systems for operations and facility management. Sensors implanted in the building send live data to the digital twin, allowing for preventative maintenance, optimal space utilization, and energy management [4], [19].
- **Post-Occupancy Evaluation (POE)**: Architects and facility managers can employ digital twins to undertake continuous post-occupancy evaluations (POE). Architects can evaluate the performance of their design goals and make recommendations for changes by monitoring real-time usage patterns, energy consumption, and interior environmental quality.
- **Smart Cities and Urban Planning**: Urban planners can use digital twins like SmartWorldPro to predict traffic, energy demand, and disaster scenarios. This comprehensive strategy promotes the development of resilient and sustainable cities [20].
- **Disaster Response and Risk Management:** Digital twins can replicate a variety of emergency events, including fires, earthquakes, and floods. Real-time data can inform emergency responses, whilst predictive simulations can aid in the development of contingency plans [4]. **Adaptive Reuse and Retrofitting**: For adaptive reuse and retrofitting, digital twins can give a baseline of present conditions, allowing for more accurate retrofit designs and sustainability upgrades without invasive inspections [6].

The combination of simulation tools and digital twin technologies allows a seamless transition from conceptual to facility management. While simulations influence initial design decisions based on future estimates, digital twins validate and adapt those decisions using real-time data. Together, they promote the concept of a "Living Building," which evolves in response to the demands of its users and the environment [4]. This transformative potential demonstrates why simulation-driven design and digital twins are no longer optional technologies, but rather becoming mainstream practices in forward-thinking architectural organizations.

5. CASE STUDIES OF SIMULATION AND DIGITAL TWIN TOOLS

Real-world examples vividly illustrate how simulation and digital twin technologies are influencing contemporary architectural practice. The following are brief overviews of prominent projects that use each tool type.

5.1 Simulation Tool Case Studies

Bullitt Center, Seattle, USA

Miller Hull Partnership designed the Bullitt Center, which uses EnergyPlus and Radiance simulations to accomplish its net-zero energy goals. Energy modeling guided HVAC system and facade design decisions, while daylighting simulations improved occupant comfort [22], [23], [24].

Masdar City, Abu Dhabi, UAE

Masdar City's wind corridors, shaded avenues, and passive cooling systems were designed using thorough CFD simulations and energy modeling. Simulation techniques helped lower ambient temperatures and energy consumption by approximately 50% when compared to traditional cities [25].

The Edge, Amsterdam, Netherlands

Deloitte's headquarters, The Edge, used environmental simulations (using IES VE) to create an ultra-sustainable structure. Energy, lighting, and thermal simulations contributed to BREEAM Outstanding certification, with the building using 70% less energy than equivalent workplaces [26].

5.2 Digital Twin Tool Case Studies

- **Virtual Singapore:**
  The city's entire 3D digital twin enables the simulation of urban microclimates, energy usage, and catastrophe management. Architects and planners utilize it to improve green infrastructure and emergency response [27].
- **Sydney Digital Twin (Australia)**:
  CSIRO's Data61 created Sydney's digital twin, which combines 3D models with real-time metropolitan data. It is used to plan new developments, assess infrastructure performance, and simulate flood scenarios to promote sustainable urban expansion [28].
- **WillowTwin in Hudson Yards, New York.**
  WillowTwin is used in Hudson Yards, the largest private real estate development in the United States, to generate a living digital model of buildings and public areas. The twin enables energy optimization, predictive maintenance, and real-time user experience improvements [18].

5.3 Insights from the Case Studies

These examples demonstrate how simulation tools excel at predictive analysis throughout the design process, resulting in improved performance and sustainability outcomes. Meanwhile, digital twin technologies expand architectural impact beyond design, allowing for dynamic, data-driven building and urban management. Together, these tools create an ecology in which proactive design and responsive operation coexist effortlessly, embodying the future of architectural practice.

Table 1. Summary of Case Studies on Simulation and Digital Twin Tools in Architecture

Category	Project/Location	Tools Used	Purpose/Focus	Remarks
Simulation Tool	Bullitt Center, Seattle, USA	EnergyPlus, Radiance, CFD Simulations	Net-zero energy building design and daylight optimization	One of the first urban commercial net-zero energy buildings; heavy reliance on early-stage simulation.
Simulation Tool	Masdar City, Abu Dhabi, UAE	CFD simulations, Energy modeling	Urban cooling strategies, passive design	An ambitious eco-city; partially successful, facing challenges in full occupancy and cost overruns.
Simulation Tool	The Edge, Amsterdam, Netherlands	IES VE Simulation Suite	Energy efficiency, lighting optimization, BREEAM certification	World's highest BREEAM score for an office; showcases smart-building integration with simulation.
Digital Twin Tool	Virtual Singapore, Singapore	3D Digital Twin (Dassault	Urban microclimate analysis, disaster resilience, planning	Model for national-scale digital twins; strong integration across sectors.

		Systèmes platform)		
Digital Twin Tool	Sydney's Digital Twin, Australia	CSIRO Data61 Digital Twin Platform	Infrastructure management, urban planning, disaster simulation	Focus on open data sharing; challenges include ensuring continuous real-time updates.
Digital Twin Tool	WillowTwin at Hudson Yards, USA	WillowTwin Platform	Building performance monitoring, predictive maintenance, user experience	First large-scale use of digital twin in mixed-use development; successful in predictive energy optimization.

6. CHALLENGES AND LIMITATIONS OF SIMULATION AND DIGITAL TWIN TOOLS

While simulation and digital twin technologies have revolutionized architectural practice, their adoption is not without challenges and limitations. Understanding these barriers is essential to fully harness their potential.

6.1 Challenges in Simulation Tools

- **Complexity and Learning Curve**: EnergyPlus, IES VE, and Radiance tools are complex and require specialist knowledge to set up and evaluate findings. For many architects, particularly those who are not trained in computational modeling, these tools create a steep learning curve. The complexity of input parameters, assumptions, and the interaction of many building systems can result in time-consuming and occasionally erroneous simulations [7].
- **Validation and Accuracy of Simulations**: Validation and accuracy of simulations rely heavily on quality input data and assumptions. Incomplete or obsolete building data can produce incorrect findings. Furthermore, real-world inconsistencies between simulation and actual performance are frequently caused by variances in building use, maintenance, or climatic circumstances, which undermine prediction dependability [29].
- **Computational Resources**: Simulation tools, particularly those that use complicated models such as CFD and energy simulations, can require significant computer capacity. This can lead to higher operational expenses and longer processing times, rendering simulations unsuitable for quick iterative design in some cases [30].

6.2 Challenges in Digital Twin Tools

- **Integrating Real-Time Data:** Digital twin systems rely on continuous data feeds from sensors installed in buildings or urban environments. Ensuring real-time data integration, ensuring data accuracy, and managing massive data quantities all provide considerable technical hurdles [4]. Furthermore, sensor breakdowns or data disparities can result in inaccurate information.
- **High initial costs and infrastructure requirements:** Creating and sustaining a digital twin requires significant upfront investment in hardware (sensors, IoT devices) and software infrastructure. These expenditures can be too expensive for smaller design companies or structures with tight budgets, limiting the general adoption of digital twin technology [31].

- **Data Privacy and Security**: Digital twins collect and process massive volumes of real-time data, including sensitive operational and user data, raising privacy and security concerns. Ensuring compliance with data privacy standards and protecting against cyberattacks is critical but difficult (Bashir et al., 2021).

7. FUTURE DIRECTIONS IN SIMULATION AND DIGITAL TWIN TECHNOLOGIES

As simulation and digital twin technologies advance, the future of architectural practice promises even more innovation. Several developing trends and research topics are predicted to shape the evolution of these technologies in the coming years.

7.1 Integration of AI with Machine Learning: One of the most promising advances is the combination of artificial intelligence (AI) and machine learning (ML) with simulation and digital twin technologies. AI can improve predictive modelling by analysing large datasets to detect patterns and optimize design solutions in real time. In digital twins, ML algorithms can interpret real-time data, allowing for adaptive design changes and self-optimizing building systems. This will eliminate the need for manual interventions and enable buildings to respond dynamically to changing situations [32].

7.2 Real-Time monitoring and automation: Advances in Internet of Things (IoT) technologies and sensor networks will allow for more sophisticated real-time data collecting, resulting in automated building management systems. Architects and building managers will be able to make real-time decisions on energy use, occupant comfort, and system performance, boosting operational efficiency and sustainability [33].

7.3 Interoperability and open standards: The future also holds the possibility of better interoperability among various digital technologies. Open standards such as BIM (Building Information Modeling) and IFC (Industry Foundation Classes) are intended to accelerate the integration of simulation and digital twin tools across platforms. This will enable seamless information flow and more integrated processes across the whole lifecycle of buildings and infrastructure, from design to operation [34], [35].

7.4 Expanding urban-scale applications: As digital twin technologies advance, their uses will expand from individual buildings to entire cities. Urban planners will increasingly use digital twin ecosystems to simulate traffic patterns, energy consumption, and environmental conditions. These models will allow for more informed policy decisions and more sustainable urban development strategies, especially in the face of global concerns like climate change and overpopulation [36].

8. CONCLUSION

Simulation-driven design and digital twin technologies have already had a significant impact on architectural practice, allowing for more efficient, sustainable, and responsive designs. Simulation technologies enable designers to forecast and optimize building performance, improving energy efficiency, thermal comfort, and overall sustainability. In contrast, digital twins give a dynamic, real-time picture of a building or urban space, allowing for continual optimization, operational efficiency, and improved resource management throughout the facility's existence. Despite their enormous potential, these systems confront numerous problems, including complexity, high starting costs, data integration, and real-time monitoring. However, continued advances in AI, IoT, and machine learning are projected to overcome these obstacles, increasing the usefulness and accessibility of simulation and digital twin technologies. Furthermore, as these technologies advance, the interoperability of various digital tools and their integration with urban-scale applications will create new opportunities for smarter, more sustainable cities. The future of

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architecture is to use these technologies not only for design, but throughout the lifecycle of buildings and urban surroundings. As the digital world expands, architects, engineers, and urban planners must work together to harness the power of these tools to design buildings that are not just intelligent and responsive but also robust to future problems.

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ISBN 978-93-342-4408-3

Revolutionizing Vertical Transportation: Advancements in Elevator Technology for Tall Buildings

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Abstract

Elevator systems are crucial for efficient building operation and occupant comfort. Recent technological innovations have revolutionized elevator design, enabling the creation of more complex and sustainable buildings. This paper explores the impact of cutting-edge elevator technologies on tall building development, highlighting examples of existing structures and future models. The study examines the benefits of advanced elevator systems, including energy efficiency, safety, and enhanced passenger experience.

The paper compares traditional traction elevators with latest designs, such as Ultra Rope, Green lifts, twin elevators, machine-room-less elevators, and electromagnetic levitation technology. These advancements empower architects to design innovative and sustainable buildings, prioritizing speed, comfort, security, and maintenance. Case studies of mega-tall buildings, including One World Trade Centre, Burj Khalifa, and Kingdom Tower, demonstrate the future of elevator technology in shaping urban skylines.

This research highlights the significance of elevator technology in modern building design, emphasizing the need for sustainable, efficient, and safe vertical transportation systems. The findings provide valuable insights for architects, engineers, and building owners, informing the development of future tall buildings that prioritize occupant comfort and environmental sustainability.

Keywords: *Vertical transportation, elevator technology, sustainable buildings, energy efficiency, safety, passenger experience.*

INTRODUCTION

Efficient vertical mobility is a critical element of tall building development and construction. The art of the elevator—moving people vertically through structures—is fundamentally about controlling gravity. It must be overcome to move people safely and effortlessly, and harnessed (through counterweights and other means) for further control and energy savings. The evolution of safety elevators which was designed in the 1850s by Elisha Graves Otis with the introduction of the safety gear allowed the skyscraper to reach new heights. The skyscraper arguably grew with the advancement and procurement of the passenger elevator.

Elevator technology and skyscraper architecture have had a symbiotic relationship for more than a century, with improvements in one encouraging new development in the other. Tall buildings could not have become what they are today without elevators and their support structures. Elevators have been responsible for reshaping modern cities by concentrating large masses of people and human activities in a smaller footprint, creating vibrant communities. It is considerably accepted that continued population growth will lead to increased urbanization, resulting in the growth of much taller structures.

However, traditional elevators are not the appropriate choice for the forthcoming requirements which leads to the exploration of new technological advancements. New advances in elevator technologies are likely to reshape cities further by enabling more effective and indeed taller buildings. Efficient vertical transportation has the ability to limit or expand our capability to build taller skyscrapers, and recent innovations in elevator design pledge to significantly reduce energy consumption. The paper discusses technologies that focus on the passenger experience, including *speed, comfort, security, energy consumption and maintenance*. Finally, it addresses future aspects of elevator upliftment through various

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mega tall buildings including One World Trade Centre, New York; Burj Khalifa, Dubai; Kingdom Tower, Jeddah.

HISTORY OF ELEVATORS

In 1854, Elisha Otis used theatrics to demonstrate the effectiveness of his new lift, with the safety brake. To show his safety mechanism at New York's version of the Crystal Palace, he cut the cables on the platform while he was standing thereon, elevated above the crowds. That was the crowd-pleasing moment that led to lifts being brought up from the mineral mines and into city skylines. The explosion in skyscrapers from the end of the 19th century to the modern day is the direct result of Otis's showmanship.

Working of typical elevators: The principal means of vertical transport is the conventional roped elevator. It moves by an immediate direct current through electric motor, which uplifts and lowers the cab in a shaft with steel wire ropes running over a series of sheaves at the motor and the cab itself; the ropes terminate in a sliding counterweight that moves up and down the same shaft as the cab, reducing the energy required to maneuver the elevator. Elevator movements are often controlled by a software that responds to signals from call buttons on each floor and from floor-request buttons in each cab.

The number of elevators in a building is determined by the peak number of people to be moved in a five-minute period. People tend to become impatient after 28 seconds of waiting, irrespective of the height of the building. So, the speed factor lacks somehow when it comes to a tall building. Moreover, the maximum reach of these elevators is 1700ft. after which the ropes start to snap due to various loads acting on it. This becomes a major drawback of conventional elevators as it sets a limit to reach the maximum height along with higher energy consumption.

Thus, these types of elevators are incompatible with the growing needs of advanced structural requirements and incredibly higher buildings which require certain improvements for efficient vertical circulation.

INNOVATIONS IN ELEVATOR TECHNOLOGY

Improvements in elevator safety, robustness, quality, space efficiency, and performance have allowed buildings and cities to grow mega tall. The design and construction of such buildings and their vertical transportation systems need to be balanced with improvements that reduce passengers' anxiety while increasing convenience and efficiency. They are designed to meet the current needs and future expectations of an increasingly connected world.

1. GEARED AND GEARLESS MOTORS

High-rise buildings typically employ geared or gearless traction elevators capable of high or variable speed operation. In geared machines, the electric traction motor drives a reduction gearbox whose output turns a sheave over which the rope passes between the car and the counterweights. In contrast, in gearless elevators, the drive sheave is directly connected to the motor, thereby eliminating gear-train energy losses. Therefore, a major advantage of gearless motors is they save about 25 percent more energy than geared motors. Gearless motors also run faster and enjoy greater longevity because they feature higher torque and run at lower RPMs. The major disadvantage of gearless elevators is cost; materials, installation, and maintenance are generally more expensive than geared elevators. In spite of the cost, more elevators use AC, gearless motor machines because they are more efficient and last longer.

2. MACHINE-ROOM-LESS (MRL) TECHNOLOGY

MRLs are fundamentally different from normal traction elevators in that they eliminate the need for an elevator machine room on the roof of the building, which is in general 8-feet taller. Machine Room-Less (MRL) lifts are traction elevators that feature a compact motor drive mounted on the car itself (Figure 1). They don't require any separate elevator machine room. The machine room is highly expensive as it is constructed to support heavy machinery.

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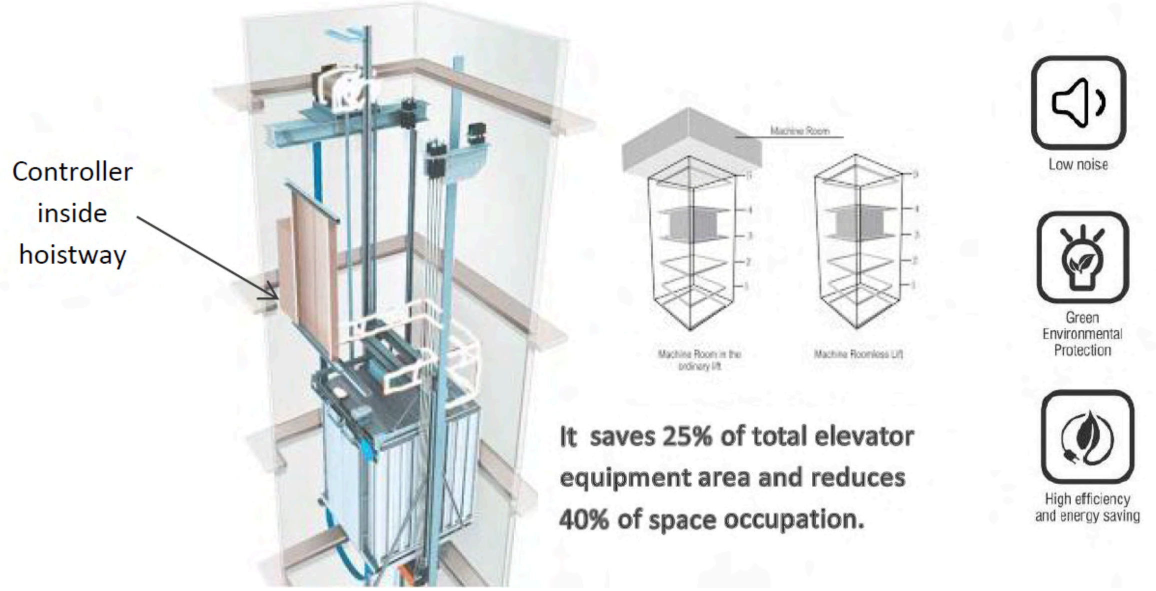

Figure 1 Machine Room Less Elevators showing compact motor drive attached with the car itself, which increases usable spaces (Source:http://tandemtechnologies.in/product-detail/mrl-elevator/7/)

Gearless machines and counterweight configuration of MRLs increases energy efficiency and provides a smoother, quiet ride. MRL lifts not only allow architectural flexibility, but also provide faster movement with noise reduction, powerful motor and energy-efficient transportation (uses about 40 percent less energy than conventional traction machines and produces less heat).

3. ELEVATOR ROPE

Elevator ropes are highly engineered and made of steel with other composites. They are several strands of various sizes wrapped together (Figure 2). A typical cable or rope can have over 150 strands of wire precisely designed to be strong, flexible, and give long service. However, in supertall and mega tall buildings, as these ropes get longer, they get extremely heavy and the rope weight increases exponentially with height. In very tall buildings, ropes may stretch for too long, adding dozens of tons of additional weight that can result in the rope breaking or snapping. In very tall buildings, almost 70% of the elevator's weight is attributed to the cable itself, and when the rope gets too long it cannot support its own weight. Many elevator companies have been working on improving cable capabilities. The most effective breakthrough is designed by KONE.

The Ultra Rope (Figure 3) comprises a carbon-fibre core and a unique high-friction coating, making it extremely light and enabling cars to travel up to 1000 m (3280 feet). This is double the current maximum distance of 500 m (1640 feet) that cars can travel. Due to the change in rope material, it gives Ultra Rope superior rope life more than twice of that compared to steel. Further, in the case of maintenance and repair, the lighter Ultra Rope would require much less time for replacement than regular ropes, reducing downtime considerably. This large decrease in weight also reduces the energy needed in the acceleration and deceleration phases, resulting in about 15% energy reduction. Ultra Rope can manage higher temperature than steel ropes before they snap under load, and they are also halogen free. Also, due to its lightweight nature, the natural frequencies are much higher than those of steel ropes. This also means that the ropes are hardly affected by rope sway.

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Figure 2 Traditional steel cables

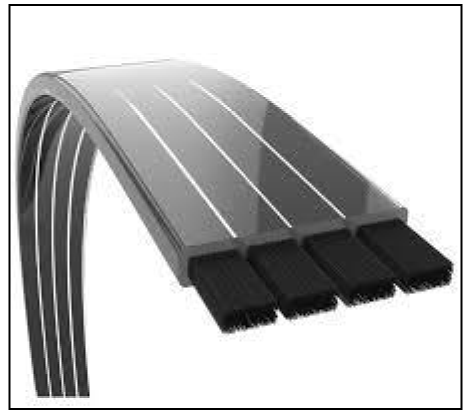

Figure 3 KONE Ultrarope

(Source: KONE corporation)

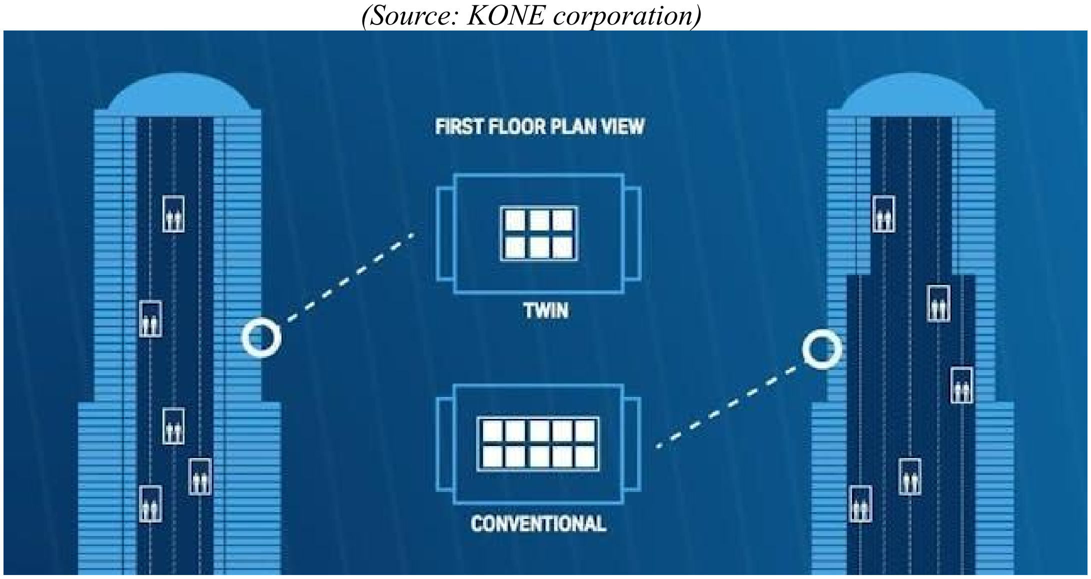

Figure 4 The difference between the Conventional and TWIN system (Source : https://www.bdcnetwork.com/home/news/55160059/thyssenkrupp-elevator-develops-twin-system-where-cars-share-an-elevator-shaft)

4. THE TWIN SYSTEM

In this system, there are two cabs which run independently in one single shaft. The system keeps a safe distance between the two elevators (upper and lower cabins) that are running on top of each other. Both cabins use the same guide rails and landing doors. Each car is equipped with its own traction drive, controller, ropes and counterweight. An intelligent Destination Selection Control (DSC) system optimizes the travel of both cabins in assigning the most efficient destinations for passengers, providing efficient service that minimizes wait time and provides fewer stops and empty trips.

The TWIN system basically provides savings in space as it cuts the number of shafts needed by one-third, compared to conventional elevators. It gives the same conveyance capacity in 25% less space. TWIN system reduces required building materials for shafts, also there is only one control machine for both elevators, leading to additional savings on space, energy and cost. Further advancement is often done by combining the TWIN lift with non-TWIN lifts. The latter serves passengers who want to travel directly, for example, from the lowest floor to the top floor and vice versa.

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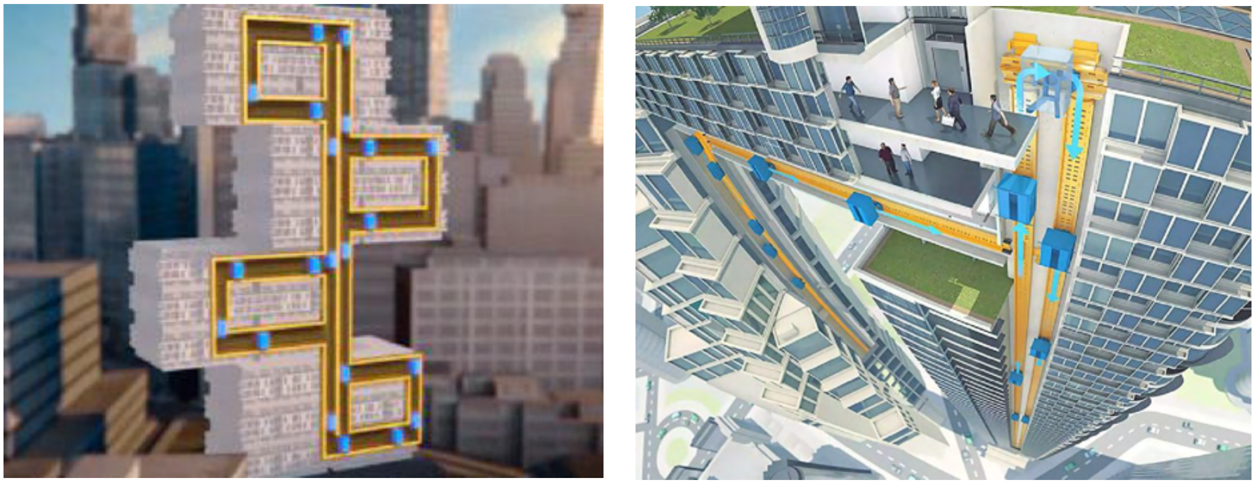

Image 5 MULTI Maglev technology where the cars are moving both in horizontal and vertical
(Source:https://qz.com/303624/maglev-elevators-are-coming-that-can-go-up-down-and-sideways/)

5. MAGLEV TECHNOLOGY

Magnetic levitation or Maglev is the same technology used in some high-speed trains such as the Shinkansen in Japan. The elevator uses a maglev track in the building which is embedded with coils to guide the cabins through a moving magnetic field. (Figure 5).

ThyssenKrupp unveiled a new and innovative elevator system capable of not only addressing the drawbacks but also, accomplishing one of the most sought features in elevators: the ability to move horizontally. This way, Maglev can replace the traditional cable and counterweight design with a linear motor that can change directions from vertical to horizontal with ease. The system also allows more than two cabins per shaft as each cabin can operate independently from one another, reducing waiting time for passengers and increasing capacity up to 50%. They are also 25% smaller than traditional ones which allow considerable savings in floor space.

The main disadvantage is being cost competitiveness as maglev technology is not cheap and replacing the system in case of problems can be expensive or sometimes even impossible hence, the need for extensive testing showing its exceptional reliability to eliminate concerns regarding potential risks.

CASE STUDIES :

The following case studies are illustrated in order to study the implementations of new elevator technologies in megatall buildings including : One World Trade centre, Burj Khalifa and Kingdom Tower.

1. One World Trade Centre, New York, USA

Height: 541 m, 1776 feet
Total Floors : 104
Architect: Skidmore, Owings & Merrill
Completion: 2014

The 104-story WTC has 71 elevators, five of which are express elevators with a top speed of 10.16m/s with a capacity of 4000 pounds (Figure 6 represents the arrangement of elevators). Initially, the speed was 9.1m/s which was increased to 10.16m/s to accommodate the increment in number of visitors in the structure which was served through normal traction elevators.

In addition to this, an elevator needs more than just robust motors to travel at high speeds. Fast moving elevators require incredibly smooth rails and rail joints to move effortlessly. In response to this problem, ThyssenKrupp has devised for the One WTC computerized roller guides that mitigate the impacts of the

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bumps in the guide rails by exerting forces in the opposite direction. Roller guides keep an elevator's wheels in contact with the guide rails as the car ascends and descends. The rollers are made of polyurethane so they can absorb slight imperfections in the rail joints. These active roller guide systems function as intelligent shock absorbers that respond in real-time.

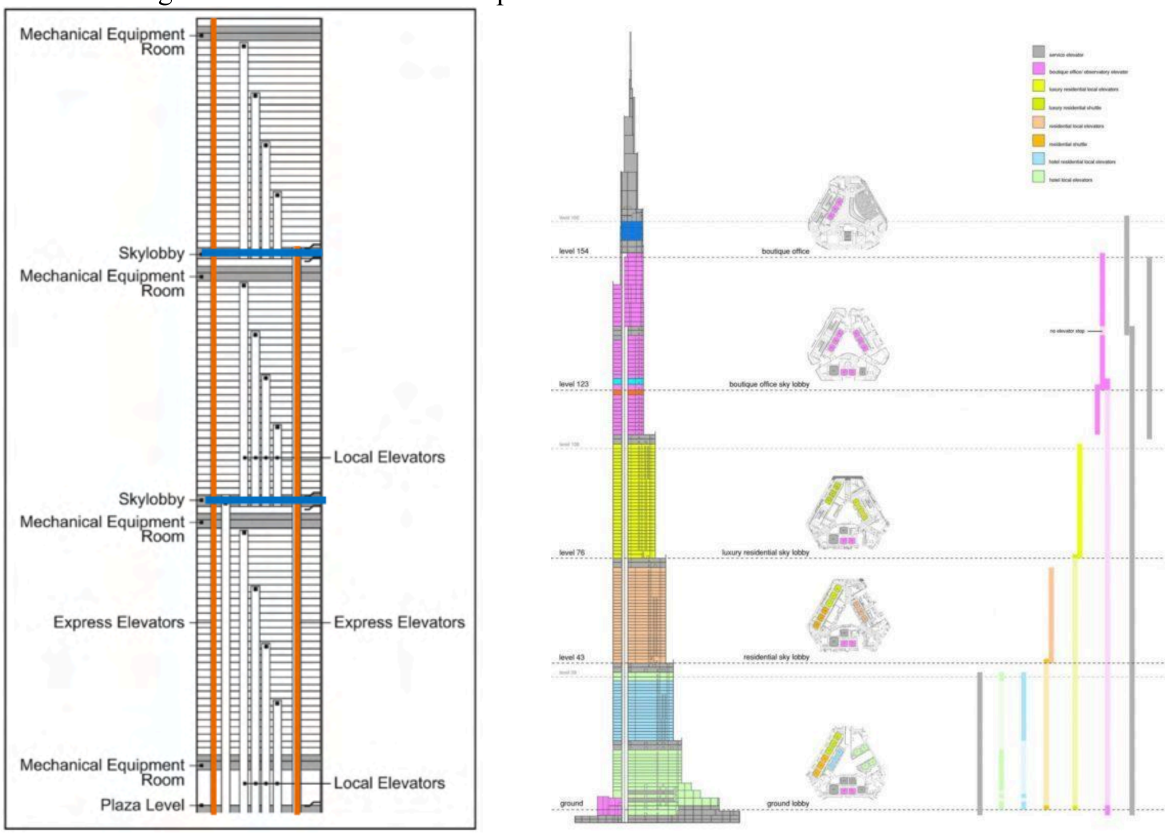

Figure 7 Burj Khalifa - Arrangement of Elevators (Source: https://skyscraper.org/exhibitions/worlds-tallest-building-burj-dubai/)

2. Burj Khalifa, Dubai, UAE
Height: 828 m, 2717 ft
Total Floors : 163
Architect: Skidmore, Owings & Merrill
Completion: 2010

Burj Khalifa is the tallest building in the world. The tower was designed as a centrepiece of a grand plan for a large mixed-use development. It consists of 57 elevators, out of which, two are double-deck elevators used exclusively for travel to the observation deck. The tower boasts a number of outstanding elevator features including: long travel distance of 504 m (1654 feet), the highest elevator landing at 638 m (2093 feet), and fast double-deck elevators that travel with a speed of 10 m/s. The express elevators, with a capacity of 12 to14 people, terminate at the sky lobby at floor level 123, houses for office space (Figure7). The sky lobby is an intermediate floor where residents, guests, office staff will change from an express elevator to a local elevator, which stops at every floor within a certain segment of the building.

Moreover, there are 24 'green technology' MRL elevators featuring flat polyurethane coated seat belts that reduce energy consumption by up to 50 per cent compared with conventional units. These energy-efficient, Gen2 elevators do not require any additional lubrication, making them cleaner for the environment.

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3. Kingdom tower, Jeddah, Saudi Arabia

Height: 1000 m, 3280 ft
Total Floors : 170
Architect: Adrian Smith & Gordon Gill Architecture
Completion: Under construction

The Kingdom tower, currently under construction, is set to be the world's tallest skyscraper reaching one kilometre into the clouds, forming the centrepiece of the first phase of the kingdom city. The tower will consist of two sky-lobbies along with the world's highest observation deck. According to KONE, the tower will be equipped with a total of 65 elevators including: 21 MonoSpace elevators; 29 Mini Space elevators; 7 Doubledeck Mini Space elevators; and service elevators. The double-deck elevators will be the world's longest and highest with a travel speed similar to that of Burj Khalifa that is 10m/s. They will be traveling 660 m directly to the observation deck, for which a single elevator in the Kingdom Tower would require nearly 20 tons of steel rope which would pose serious construction problems. Fortunately, the Ultra Rope hoisting technology makes this possible. As explained earlier, the carbon-fibre Ultra Rope, is lighter and stronger than steel rope, which consequently reduces weight and motor size, decreases power consumption by approximately 21 percent, and allows a greater lift height.

Further, the latest KONE "People Flow Intelligence" systems will be implemented to smooth the flow of people to and from elevators and to reduce waiting time. Interestingly, high-rolling residents and VIP visitors will also be able to communicate directly with the lifts through their smartphones. They will be able to remotely call the elevator as they step out of their cars.

CONCLUSION:

Over the past many years, the elevators have witnessed major technical improvisations which allowed the construction of taller structures. Since then the skyline is adversely affected to build into the clouds. Vertical construction in modern cities and its transportation was achieved through the invention and development of elevators as one of the most important services in high-rise buildings for convenience, safety and comfort. The simultaneous demand for more space and the lack of developable land in modern cities means that we will be building up more often, and cutting edge elevator technology will play a critical role in urban development.

Through the research and the case studies, it is compared that the traction elevators equipped with the conventional steel ropes and pulley system are incompatible with the forthcoming needs of the taller structures in terms of speed, waiting-time, passenger safety, energy-efficiency and smooth movement. They do require a certain advancement to overcome the challenges faced.

By reviewing various elevator technologies, it is clear that the main focus is to reduce energy consumption while increasing speed and ensuring safe and smooth vertical transportation of the structure. Technology today allows for minimizing elevator space requirements by maximizing elevator service with sophisticated operation control mechanisms. It is crucial for the design complexity of tall structures to plan the service core effectively whilst reducing the core area which helps in increasing the saleable area of the building. Massive urbanization also forces elevator companies to further innovate and to move intellectual concepts from paper to reality. The results will be improved speed, capacity, control, energy efficiency, comfort and safety; features that will enhance the sustainability of future high-rise developments.

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ISBN 978-93-342-4408-3

Streets of Belonging: Reimagining the Marketscape of Malleshwaram through Human-Centered Design

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ABSTRACT

Markets in Indian cities are not merely transactional spaces, but culturally embedded terrains shaped by temporality, ritual, and informal negotiation. This paper, situated in the historic precinct of Malleshwaram, Bengaluru, reconceptualises the market as a marketscape—a spatially and socially dynamic field where commerce intersects with collective memory, pedestrian life, and religious practice. Anchored by arterial corridors and layered with cross-street rituals, vendor networks, and institutional anchors, the precinct offers a compelling site to examine the interplay of the formal and informal.

Employing a multi-scalar methodology—including spatial mapping, behavioural observation, and stakeholder engagement—the study analyses how rhythms of movement and use inform both spatial conflict and opportunity. It identifies challenges such as vehicular dominance, fragmented public space, and erosion of memory-embedded zones, and responds through a human-centered design framework grounded in four domains: People, Vending, Parking, and Public Space.

Rather than advocating wholesale transformation, the proposal advances an incremental design and policy toolkit—ranging from micro-interventions to a long-term tunnel strategy for traffic diversion. Ultimately, this research positions Malleshwaram's streets as cultural commons and contributes to the broader discourse on inclusive urbanism, arguing for context-responsive, memory-anchored spatial futures in the Indian city.

Keywords: Marketscape, Human-Centered Design, Urban Informality, Place Identity, Inclusive Urbanism.

1. INTRODUCTION

Markets in Indian cities extend beyond commerce, operating as cultural, temporal, and spatial lifelines. In older neighbourhoods such as Malleshwaram, Bengaluru, the market is not enclosed but unfolds across streets, thresholds, and temple fronts, shaped by rituals, informality, and pedestrian use. Yet, pressures from vehicular dominance, fragmented infrastructure, and reduced pedestrian priority are eroding this vibrancy [7]. Drawing from urban theory, the market is understood as a socio-spatial construct [4], a "third place" [5], and a vessel of collective memory [6]. This study positions Malleshwaram's market as a marketscape—a dynamic confluence of movement, memory, and informal practice [1], [2], negotiated continuously by local communities [8].

1.1 Purpose of Paper

This paper investigates Malleshwaram's street-based marketscape through spatial, temporal, and behavioural analysis, and proposes a design framework grounded in community use and adaptability. Rather than a fixed masterplan, it offers incremental, human-centered strategies to enhance walkability, support informal economies, and restore public space.

1.2 Study Area Context and Significance

Malleshwaram is one of Bengaluru's earliest planned extensions, organised by temple-street structures, institutional anchors, and vendor-linked residential zones. Sampige and Margosa Roads serve as arterial

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spines, intersected by cross streets that mediate rituals, commerce, and daily movement. The area's socio-spatial layering—marked by temple rituals, street vending, and pedestrian activity—reflects the blurred boundaries between formal infrastructure and informal adaptation [3].

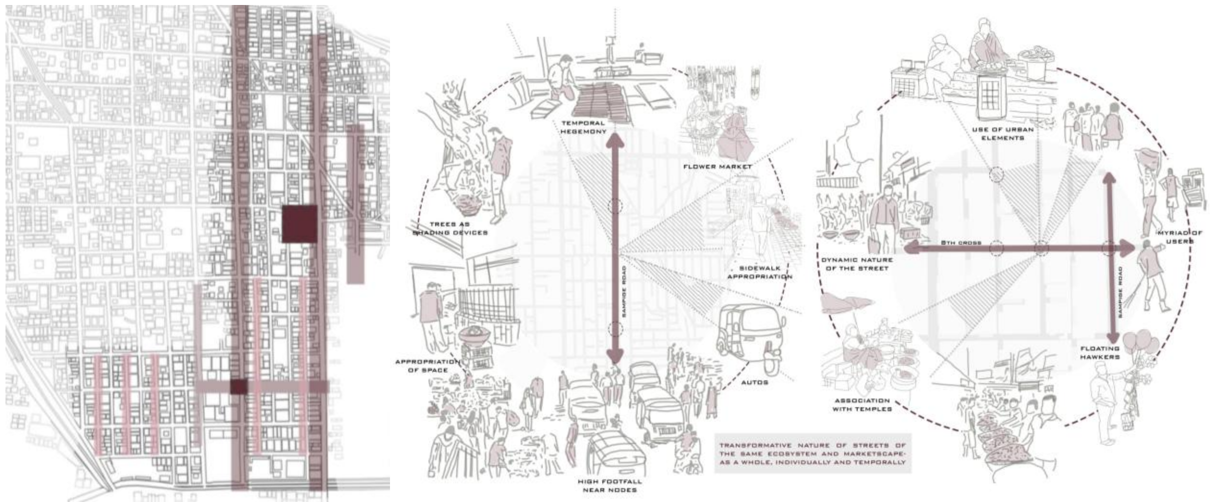

Figure 1. Neighborhood level map of Malleshwaram with study areas; Figures 2 and 3. Illustrations of temporal activities along the market streets (Source: Author)

1.3 Key Questions

- How do rhythms of movement, vending, and ritual shape spatial experience in Malleshwaram?
- What conflicts emerge at the intersection of informality, mobility, and infrastructure?
- How can design reconfigure streets to reflect lived practice without erasing cultural patterns?

1.4 Approach

The research adopts a layered methodology combining spatial mapping, temporal analysis, and stakeholder engagement. Patterns of building use, circulation, vending, and congregation were documented through behavioural observation and interviews. The findings informed a human-centered framework structured around People, Vending, Parking, and Public Space—each addressed through context-responsive design interventions.

2. LITERATURE REVIEW

Recent literature positions Indian markets not as static zones of trade, but as evolving cultural and spatial systems. This study draws on two precedent frameworks situated in Bengaluru—Keswani's analysis of temporal urbanism in Shivajinagar [1], and Patel et al.'s spatial framework for informal economies in KR Market [2]. These are supported by broader urban theory addressing public space, informality, memory, and community-driven design.

2.1 Markets as Temporal Landscapes

Keswani [1] distinguishes "ordinary" and "extraordinary" days, tracing fluctuations in public space based on ritual cycles and informal occupation. Her approach underpins this study's time-based mapping of pedestrian density, vending occupation, and ritual overlap in Malleshwaram, especially along 8th Cross and near Kadu Mallikarjuna Temple.

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2.2 Informality as Urban Logic

Patel et al. [2] advocate for integrating vendors into the city's formal structure through flexible spatial strategies. Their framework aligns with Roy's argument that informality is a mode of survival rather than an aberration of planning [3]. This informs the present study's decision to treat vending as a core design layer.

2.3 Public Realm, Third Places, and Memory

Carmona et al. [4] describe public space as a synthesis of activity, meaning, and form. Oldenburg's "third place" concept [5] situates the market as a space of social cohesion. Hayden's [6] work on memory and place further positions street markets as repositories of local identity. In Malleshwaram, temple edges, flower vendors, and shaded pause points function as mnemonic anchors.

2.4 Research Gap and Contribution

While much has been written on informality or spatial structure in isolation, few studies integrate temporality, behaviour, and community practice into a design methodology. This research addresses that gap by:

- Grounding spatial strategies in observed, time-bound patterns
- Integrating user needs and informal dynamics into public space design
- Framing the street not as infrastructure alone, but as a cultural commons

3. METHODOLOGY

This research adopts a spatially embedded, ground-up methodology informed by both behavioural mapping and community consultation. The approach aligns with Keswani's urban fieldwork model [1], combining empirical observation with time-sensitive ground-truthing.

Field mapping documented variations in pedestrian movement, vendor presence, ritual flows, and vehicular dominance across key arteries—Sampige Road, Margosa Road, and 8th Cross. Activity was tracked over weekdays, weekends, and festival days, capturing temporal intensities. Vendor occupation and pause-point usage were studied through 30-minute observation cycles. Semi-structured interviews with local vendors, temple-goers, shop owners, and residents illuminated lived challenges, coping strategies, and shifting practices. These findings informed a spatial-temporal analysis that identified layered pressures—vehicular conflict, shrinking pause zones, contested vending areas—overlaid with cultural memory and everyday rhythm.

4. OBSERVATIONS AND FINDINGS

4.1 Pedestrian Conflict and Vehicular Dominance

The unidirectional traffic system on Sampige and Margosa Roads prioritises through movement over local use. Despite high footfall, pedestrian space remains constrained and often disrupted by parked vehicles, informal vendors, and uneven surfaces. The disconnect between movement hierarchies and lived behaviours generates conflict at critical junctions and temple thresholds.

4.2 Temporal Patterns in Vending

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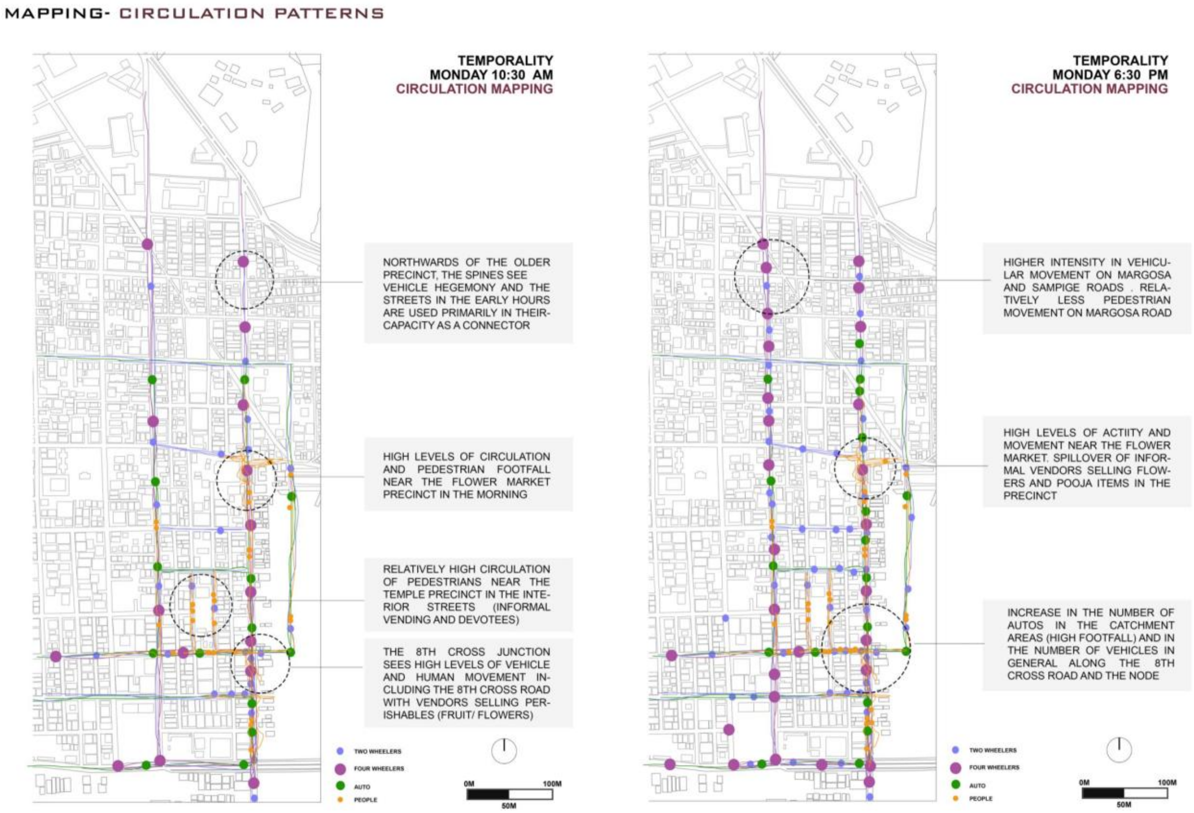

Figures 4 and 5. Circulation patterns of different stakeholders, temporally (Source: Author)

Vending patterns are dynamic and tied to ritual calendars, temple timings, and commuter peaks. Vendors occupy different edges across the day, with temporary clusters near Kadu Mallikarjuna Temple and 8th Cross intensifying during morning and evening rituals. Festival days significantly amplify spatial pressure, disrupting circulation and drawing enforcement.

4.3 Fragmented Public Space and Informal Negotiation

While informal activities bring vitality, the lack of designed public zones forces spatial negotiation. Temple forecourts, wide footpaths, and corners serve as default gathering spaces, but lack shade, seating, or legibility. These spatial fragments are sites of tension between vendors, pedestrians, and enforcement bodies.

4.4 Vulnerability of Identity and Memory

Built edges tied to cultural memory—such as flower stalls or shaded temple-front trees—face the threat of erasure due to infrastructure upgrades, traffic demands, and inconsistent regulation. The loss of spatial continuity and ritual accommodation undermines the marketscape's embedded identity.

5. DISCUSSION

The findings reveal Malleshwaram's marketscape as a complex negotiation of ritual, commerce, and movement—one that is neither fully formalised nor entirely informal. This prompts the need for a responsive design framework that integrates informality into spatial logic without imposing rigid infrastructure.

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Figure 6. SWOT analysis map (Source: Author)

5.1 Human-Centered Design Framework- The proposed framework is structured across four interconnected domains:

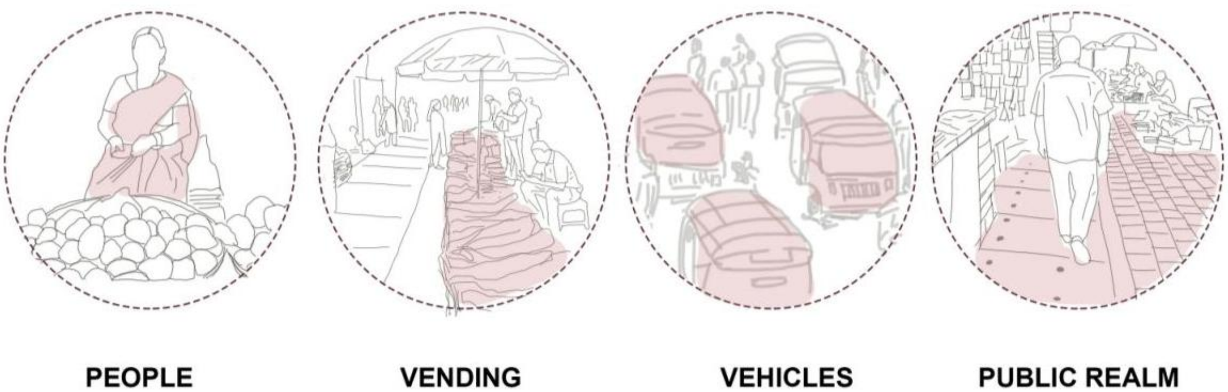

Figure 7. Illustration of the human centered design framework (Source: Author)

- **People**: Design prioritises pedestrian experience, ritual access, and shaded rest points through widened footpaths, tree retention, and minimal seating.
- **Vending**: Vending zones are demarcated based on temporality and product category, with designated stalls near religious and institutional anchors.
- **Parking**: Time-bound loading zones and consolidated parallel parking are introduced, freeing up key pedestrian corridors.
- **Public Space:** Temple edges, street corners, and underused verges are redesigned as pause points with modular furniture, flexible edges, and spatial definition without over-formalisation.

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5.2 Typology-Based Interventions- Three repeatable typologies were developed:

- **Temple-Edge Typology** – Semi-permanent platforms and shaded seating that allow rituals and vending to coexist.
- **Shared Street Node** – Junctions redesigned with continuous surface materials, low kerbs, and vendor-integrated buffers.
- **Pause Point Retrofit** – Existing shade-providing trees protected and enhanced with seating rings and lighting, establishing social anchors.

6. DESIGN PROPOSAL

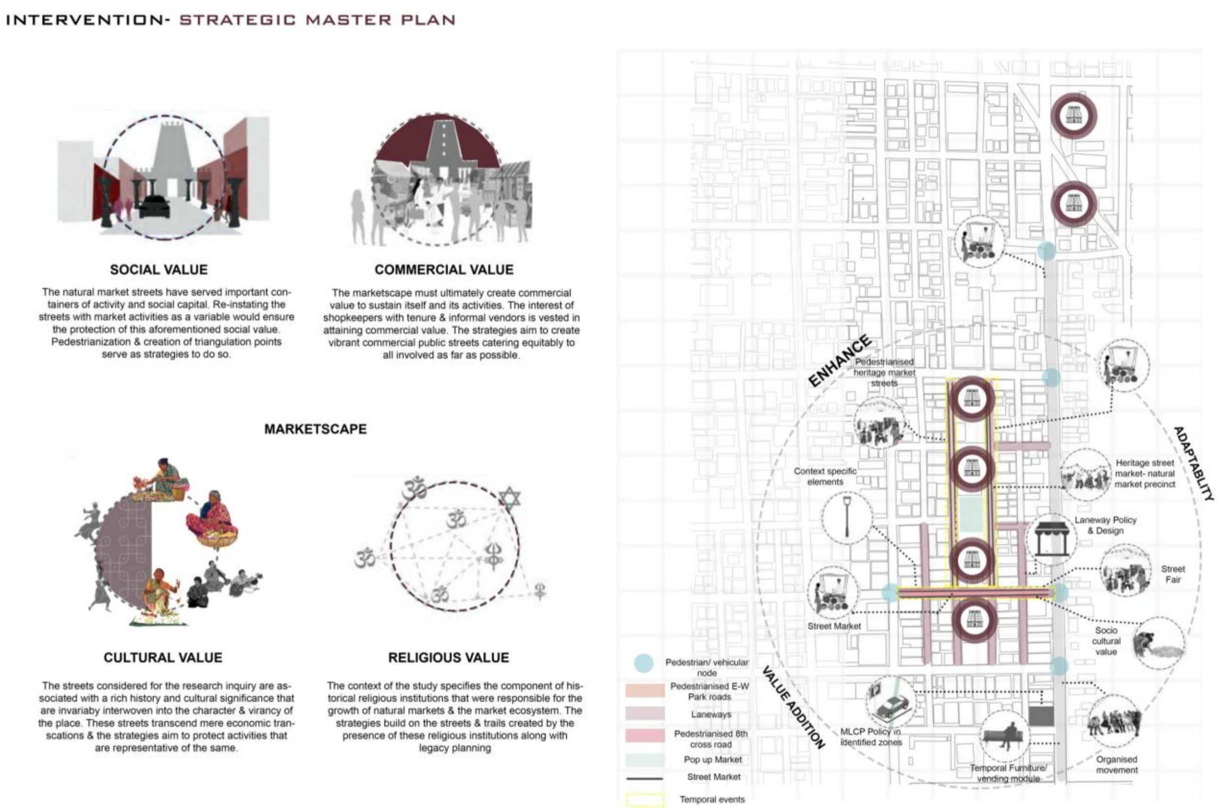

Figure 8. Illustration of the various values to be leveraged and the strategic master plan (Source: Author)

The spatial strategy culminates in a design toolkit that addresses both short-term needs and long-term transformation:

A. **Short-Term**: Bollard-defined vending bays, signage-led footpath regulation, and shaded micro-rest zones.

B. **Medium-Term**: Uniform footpath widths (1.8–2.4m), embedded seating, and unified surface materials across 8th Cross and temple-fronts are consistent with walkability standards recommended by UTTIPEC [9].

C. **Long-Term**: Sampige Road tunnel diversion—a high-impact strategy to shift through traffic underground—releases surface area for a fully walkable cultural corridor, integrating vending pockets,

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widened pedestrian movement zones, and active temple thresholds. The surface-level becomes a shared market spine prioritising memory, mobility, and cultural identity.

Each phase balances feasibility with transformation, ensuring that infrastructural changes are embedded in lived rhythm and ritual logic.

CONCLUSION

Malleshwaram's marketscape cannot be resolved through conventional planning paradigms. It must be reframed as a cultural commons—a street-based ecosystem where ritual, commerce, memory, and infrastructure interact. This research offers a design methodology rooted in observation, temporality, and informal logic, contributing to the discourse on inclusive urbanism in Indian cities. By leveraging what already exists—edge conditions, informal practices, and cultural anchors—this study proposes a new grammar of intervention: one that does not overwrite, but extends. In doing so, it positions Indian markets not as relics of the past, but as critical prototypes for designing socially just, memory-rich, and adaptive urban futures.

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ISBN 978-93-342-4408-3

Future Hospital Building Design Post Pandemic: A Literature Review

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Abstract

The COVID-19 pandemic revealed major weaknesses in hospital design and healthcare infrastructure across the world. Hospitals faced challenges like overcrowding, poor ventilation, and difficulties in controlling infection spread. This literature review focuses on how hospital buildings can be improved in the post-pandemic era. Using a systematic review approach based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) tool, twenty studies published between 2020 and 2025 were analyzed. The review identifies key strategies for future hospital design, including creating flexible layouts that can quickly adapt during emergencies, improving air ventilation systems, and incorporating smart technologies like sensors, touchless systems, and telemedicine to minimize direct contact. It also highlights the importance of using antimicrobial and easy-to-clean materials to limit infection risks. Modular construction, which allows hospitals to be built offsite and assembled quickly, is presented as an effective method for creating emergency healthcare facilities. While these strategies offer many benefits, the review notes challenges such as high costs and the difficulty of implementation in low-resource areas. Therefore, strong collaboration between architects, engineers, healthcare workers, and policymakers is needed. Overall, the study concludes that hospitals of the future must be adaptable, technology-driven, sustainable, and patient-centered. Rather than reacting to emergencies, healthcare infrastructure must be prepared in advance. This review provides important insights into designing safer, smarter, and more efficient healthcare spaces that can better support patients and healthcare workers during both everyday operations and crisis situations.

Keywords: - *Pandemic, Post Pandemic, COVID-19, Future Hospital, Hospital Design, Pandemic Hospital, Coronavirus.*

INTRODUCTION

The COVID-19 pandemic has had an impact on healthcare systems worldwide and a significant influence on India, the world's second largest populated country. Healthcare has been affected by COVID-19, as has every other sector in the nation. Due to the huge pressure of the worldwide pandemic, the Indian healthcare system collapsed, exposing the shortcomings and difficulties in the current system of health delivery. (Megha Kapoor, 2023)

Corona-virus disease (COVID-19) patients display a wide spectrum of symptoms, from minor to moderate. All ages are affected, although as people age, their risk of developing a serious infection rises. Individuals with a corona-virus infection who also have pre-existing co-morbidness including diabetes, asthma, or cardiovascular illnesses (CVDs) are at a higher risk of developing adverse outcomes or passing away. Through the droplets released when coughing or sneezing, a healthy person can directly contract COVID-19 by close contact with an infected person. Additionally, it can spread indirectly by contact with contaminated objects, such doorknobs. A person may encounter breathing difficulties or shortness of breath, in which case they need immediate medical assistance. Following viral exposure, these symptoms could show up 4–5 days later or as long as 14 days later. They could also be asymptomatic. (Megha Kapoor, 2023)

The unexpected challenges presented by the pandemic, such as rise in patient numbers and the need for effective infection control, have emphasized the importance of resilient and adaptable hospital designs. As the global healthcare sector transitions to a post-pandemic era, there is a need to rethink hospital architecture to address these challenges and ensure preparedness for future health crises. (Nirav Nimavat, 2022). The COVID-19 pandemic had a massive impact on healthcare systems worldwide, exposing serious gaps in hospital design and healthcare delivery. (Megha Kapoor, 2023) Hospitals faced challenges such as overcrowding, poor air quality, cross-infection, and limited flexibility to handle sudden surges in patient numbers. (Iskandar, 05 Aug 2024) The pandemic made it clear that future hospitals must be designed differently — focusing on flexibility, infection control, better air ventilation, and the use of smart technologies. (Abeer Makram, 2022) In India, for example, the healthcare system struggled with shortages of oxygen, ICU beds, and ventilators, showing the urgent need for better planning and stronger infrastructure. (Megha Kapoor, 2023) Studies also showed that modular construction techniques, like building hospitals quickly off-site using steel-framed units, played a major role in emergency response during COVID-19. (Perampalam Gatheeshgar, 2021) In places like Wuhan, emergency hospitals such as Huoshen Shan Hospital were built within days, using designs that separated clean and contaminated areas and used special air ventilation systems to limit infection spread (Yanhua Chen, 2021).

This paper provides a comprehensive literature review on future hospital building design, collecting data from lessons learned during the pandemic. It explores growing principles and practices that aim to transform hospital infrastructure, focusing on innovative architectural strategies, and spatial planning techniques. Key aspects discussed include designing spaces to optimize infection control, enhancing operational efficiency, integrating telemedicine capabilities, and incorporating sustainable practices to align with environmental priorities.

Methods

This literature review follows a systematic methodology to explore the future of hospital building design in the post-pandemic era. The research begins by defining its scope, focusing on key aspects such as infection control, adaptability, and patient care. Data was collected from scholarly articles, and expert insights published between 2020 and 2025, sourced from academic databases like Scopus. While irrelevant or non-empirical works were eliminated, the inclusion criteria made sure that only peer-reviewed and reliable articles were chosen. The results were combined into clear themes to provide a thorough understanding of how hospital infrastructure can evolve to create resilient, adaptive healthcare systems for future challenges

This PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart outlines the process of selecting studies for this literature review. A total of 20,000 records were initially identified through Scopus. After removing studies based on publication year and relevance, 45 full-text articles were assessed for eligibility. Following further screening, 25 studies were excluded for not meeting the inclusion and exclusion criteria. Reason being -overlapping data (n =9), Layout intervention in future hospitals (n =16) and 20 studies meeting the inclusion criteria were finally selected for the review. The diagram shows the stages of identification, screening, eligibility assessment, and inclusion *as shown in Fig.1*.

Inclusion and exclusion criteria

This systematic review included the studies that directly address the research question or topic and must be published in peer-reviewed journals or reliable sources and the publication must be from 2020 to 2025.

The excluded studies are studies with incomplete or insufficient data and the studies outside the research topic or focus area and also duplicate publications or studies with overlapping data. Also, the research with methodological flaws or poor-quality assessments were removed.

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Identification of studies via databases and registers

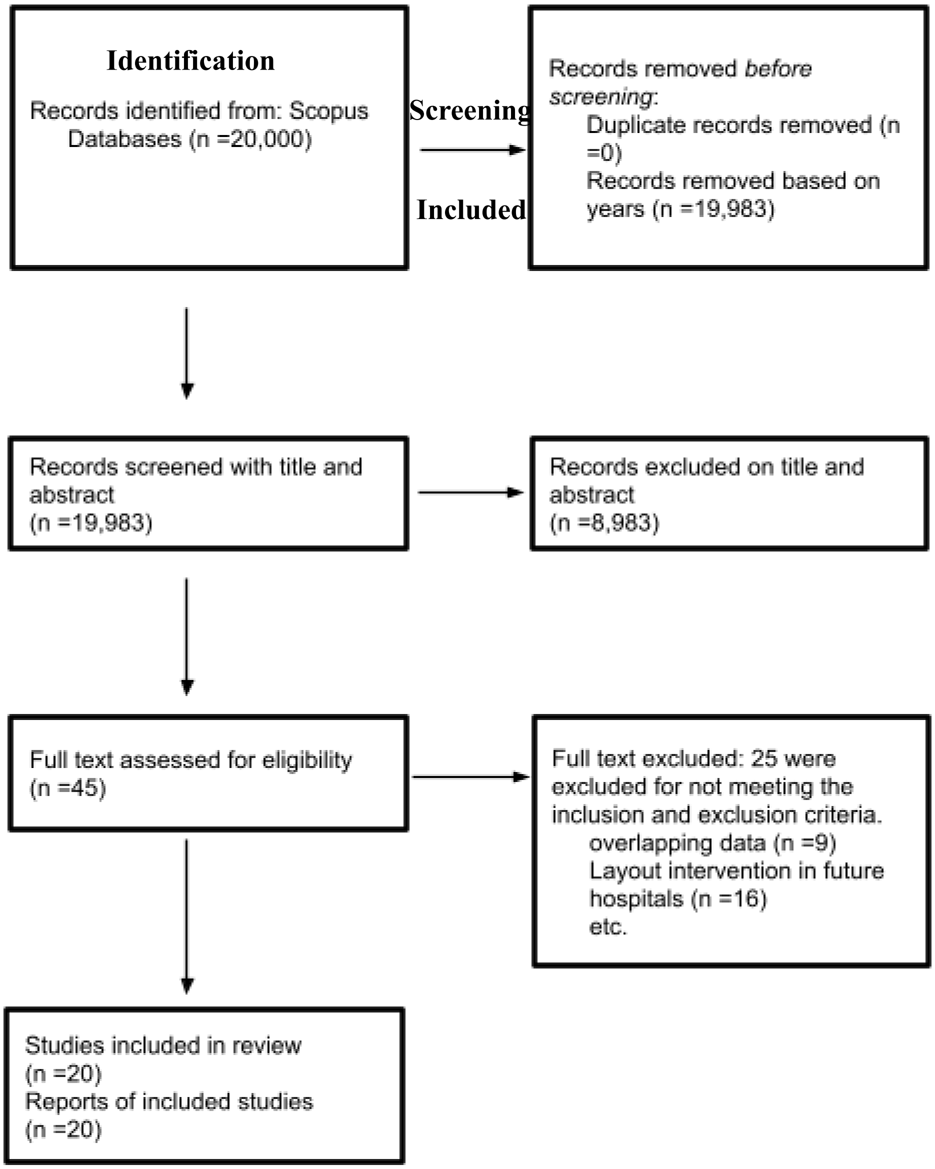

Figure 1- PRISMA (Megha Kapoor, 2023)

2. Literature Review

Some main ideas from the studies are:

I. New hospital design strategies like more flexible layouts, better air ventilation, use of smart technology (like sensors and touchless systems) (Sang-Jun Park, 2022), and natural elements (like light and plants) (Abeer Makram, 2022).

II. Telemedicine (remote healthcare through technology) became very important to limit face-to-face contact (Megha Kapoor, 2023).

III. Modular construction (building parts of hospitals quickly offsite) was used for emergency hospitals (Md Haseen Akhtar, 2023).

IV. Use of special materials like antimicrobial surfaces to prevent virus spread (Isabella Nuvolari-Duodo, 2024).

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V. Separation of infected and non-infected areas inside hospitals to avoid cross-contamination (Ivo Casagranda, 2022).
VI. Better preparation for future pandemics by building hospitals that can quickly adapt during emergencies (Ivo Casagranda, 2022).
VII. Problems faced: In countries like India, the pandemic showed gaps in healthcare facilities, like a shortage of oxygen, ICU beds, and ventilators, but it also boosted new technologies like mobile health apps (Isha Goel, 2021).

3. Result

A systematic literature review was conducted to analyze how hospital design has changed because of the COVID-19 pandemic. The objective of the review is to explore the new principles of future hospital building design, addressing critical lessons learned during the pandemic. Review includes studies from different countries like Egypt, India, Korea, and Italy. Each study talks about ways to improve hospital buildings so they can handle future health emergencies better (Pragati B Hebbar, 2020).

The main goals of these studies were to explore and identify effective strategies for designing hospitals that are better equipped to handle future health crises. Researchers aimed to analyze the challenges that hospitals faced during the COVID-19 pandemic, such as overcrowding, infection control failures, and poor space management. By understanding these shortcomings, the studies sought to propose innovative design solutions that use technology and smart planning to improve safety, flexibility, and efficiency in healthcare environments *as shown in Fig. 2.* The goal was not only to fix past issues but also to prepare hospitals for any similar emergencies in the future (Si Gao, 2023).

Some key ideas that came out of the research include the importance of creating separate zones and dedicated routes within hospitals to control the spread of infections and reduce cross-contamination. The use of smart technologies, such as the Internet of Things (IoT), was also needed to help monitor patient conditions and manage hospital resources more effectively (Satheeskumar Navaratnam, 2022). Several studies tells the need for hospital spaces to support social distancing and ensure proper ventilation to maintain air quality. Flexibility in design was seen as crucial—allowing hospital spaces to be quickly adapted or reconfigured during emergencies (Porebska, 2022). Additionally, the studies stressed the importance of designing with the needs of both healthcare workers and patients in mind, ensuring comfort, safety, and functionality for all users.

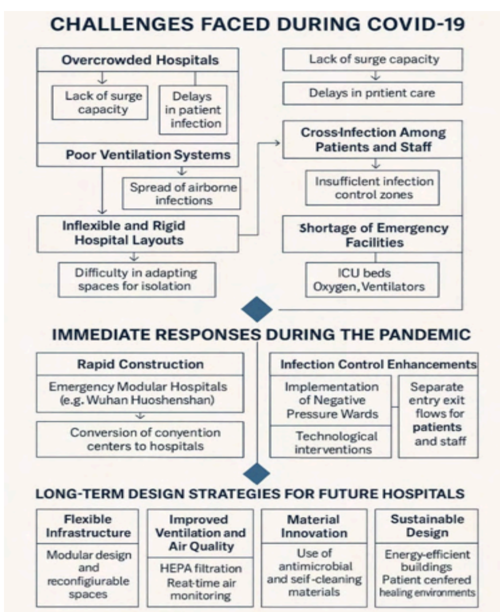

Figure 2- COVID-19 Challenges, Responses and Strategies (Costase Ndayishimiye, 2022)

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The studies use literature reviews most of them did not include direct experiments but were based on existing data and experiences during COVID-19. These review shows that future hospitals need to be more flexible, technology-driven, and focused on infection control to deal with any similar health crises.

4. Discussions

The COVID-19 pandemic has brought a significant shift in the way healthcare facilities are designed and managed. This literature review, based on twenty selected studies from around the world, highlights how urgent the need is for a fundamental rethinking of hospital infrastructure to better prepare for future pandemics and emergencies.

Flexibility and Adaptability

One of the key themes emerging from the studies is the importance of flexibility and adaptability in hospital design. Several studies emphasized that future hospitals must be designed with spaces that can be easily reconfigured in response to surges in patient numbers or outbreaks of infectious diseases (Isabella Nuvolari-Duodo, 2024). Flexible layouts, such as modular spaces and adaptable treatment zones, allow hospitals to quickly expand or contract their services depending on need. This concept was particularly stressed in research from Italy and India, where healthcare facilities faced massive overcrowding during the peak of the pandemic (Stefano Capolongo, 2020).

Air Quality and Ventilation

Another critical aspect discussed across the literature is the role of air quality and ventilation. Studies from countries like China and Jordan underlined how advanced ventilation systems, the use of negative pressure rooms, and the strategic zoning of clean and contaminated areas helped control the spread of infections (Kalu, 2020). Hospital designs incorporating natural ventilation and improved air filtration technologies were considered essential for protecting both patients and healthcare workers (Saeed Hussein Alhmoud, 2023).

Smart Technologies

Smart technologies such as the Internet of Things (IoT), automation, and touchless systems also featured heavily in the reviewed literature. Researchers from Korea and Australia advocated for the integration of smart solutions that can monitor patient health, control building systems, and minimize physical contact. These technologies not only enhance infection control but also improve operational efficiency and patient care experiences (Sang-Jun Park, 2022).

Telemedicine

Telemedicine emerged as another vital tool during the pandemic and has influenced hospital design priorities. The studies show that inpatient and outpatient areas now need to incorporate digital health capabilities to support remote consultations, monitoring, and management of patients, thus reducing unnecessary exposure (Megha Kapoor, 2023).

Material Selection

Material choice and surface design were also identified as key factors. Researchers from Switzerland and Egypt emphasized the use of antimicrobial surfaces, such as copper or nanotechnology-enhanced materials, and the importance of easy-to-clean interior finishes to limit pathogen survival (Isabella Nuvolari-Duodo, 2024) (Kalu, 2020) (Saeed Hussein Alhmoud, 2023).

Modular Construction

Furthermore, the pandemic exposed significant gaps in healthcare infrastructure, especially in countries like India, where shortages of critical supplies and healthcare staff were common. This highlighted the need for scalable emergency facilities. Studies focusing on modular construction, such as affordable steel-framed modular units, demonstrated how rapidly deployable healthcare facilities could effectively address sudden surges in demand (Isha Goel, 2021).

Despite the range of innovations proposed, the literature also notes several challenges, including the high cost of technological upgrades, implementation barriers in low-resource settings, and the need for interdisciplinary collaboration between architects, engineers, healthcare professionals, and policymakers. Overall, the findings suggest that the future of hospital design lies in creating resilient, flexible, technology-driven, and human-centered environments. These must not only address infection control but also prioritize patient and staff well-being, operational efficiency, and environmental sustainability (Perampalam Gatheeshgar, 2021).

CONCLUSION

The COVID-19 pandemic has shown us that the way hospitals are currently built is not enough to handle serious health emergencies. It exposed many problems, like overcrowded hospitals, poor ventilation, and designs that made it hard to stop infections from spreading. Because of these issues, it is clear that hospitals must be designed differently in the future to be ready for any new challenges (Abeer Makram, 2022).

From the studies reviewed in this research, it is clear that flexibility is one of the most important features for future hospitals. Hospitals need to be able to quickly change their spaces — like turning a normal ward into an isolation area — depending on the situation. Flexible layouts, modular rooms, and movable walls can help manage patient numbers better during emergencies (Stefano Capolongo, 2020).

Good air quality and ventilation also play a very big role in controlling infections. Designs that bring in more natural air, use filters, and separate clean and contaminated air areas will help hospitals keep patients and healthcare workers safe (Saeed Hussein Alhmoud, 2023).

Technology will be a big part of the hospital of the future. Using smart systems like sensors, automatic doors, and devices that monitor patient health remotely can reduce physical contact and limit infection spread. Telemedicine, which became very popular during COVID-19, must be fully included in hospital planning. It allows doctors to treat patients from a distance, helping to keep both patients and staff safe (Nirit Putievsky Pilosof, 2021).

Another important point is the choice of materials inside hospitals. Materials that are easy to clean and that kill germs, like copper surfaces or advanced coatings, can help reduce infection risks (Kalu, 2020).

The pandemic also taught us that during emergencies, we need hospitals to be built quickly. Modular construction, where buildings are made in parts and then assembled fast on-site, proved very effective. This method can help create emergency facilities, like quarantine centers or temporary hospitals, whenever needed (Abdul-Quayyum Gbadamosi, 2020). However, making all these improvements comes with challenges. Advanced technologies and modular systems can be expensive and difficult to apply everywhere, especially in poorer regions. That is why collaboration between architects, healthcare workers, engineers, and government bodies is very important. Working together, they can find solutions that are both effective and affordable (Isabella Nuvolari-Duodo, 2024).

In short, this review shows that the hospitals of the future need to be smart, flexible, patient-friendly, and ready for emergencies. Instead of just reacting to problems when they happen, we must build hospitals that are prepared in advance. By using the lessons learned from COVID-19, we can create healthcare spaces that protect, heal, and serve better in both normal times and times of crisis.

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ISBN 978-93-342-4408-3

CARVING MODERNITY: REINVENTING STONE CRAFTSMANSHIP IN MODERN ARCHITECTURE

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Abstract

This research paper examines the role of traditional Indian stone craftsmanship in modern architectural practice. The research revisits techniques such as jali work, pietra dura, and dry stone masonry that are contemporary in nature and, therefore, have always been critical to Indian architectural tradition, particularly in the face of the increasing environmental challenges and the need for cultural continuity. Stone is being re-evaluated as a sustainable alternative to energy-consuming modern materials such as steel and concrete due to its low embodied energy, high thermal mass, and centuries-long lifespan. The paper highlights how these ancient practices are being converted into precise, scalable, and functionally integrated systems without losing their handcrafted value through technological means such as CNC carving, digital modeling, and prefabrication. This study assesses the cultural, economic, and environmental impacts of returning stone to building design through case studies from contemporary India. Stone craftsmanship is not only said to enhance architectural performance and reduce lifespan costs, but also to enhance local identity and assist artisan communities, presenting a solid example of architecture for the future.

Keywords: *Stone craftsmanship, Indian architecture, sustainability, CNC carving, cost analysis, traditional techniques.*

INTRODUCTION

1.1 Background

For thousands of years, Indian stone craftsmanship has thrived, producing masterpieces such as highly carved stone sculptures mostly found in temples, monuments, and historical architecture with exquisite jalis (perforated screens), stone inlays (pietra dura). Historically, these crafts fulfilled both aesthetic and practical purposes including visual decoration, structural integrity, and passive cooling, among other uses. The architectural world has just rediscovered these ageless methods, combining modern technology with ancient creativity to produce creative, environmentally friendly, and cultural designs.

1.2 Need of the Study

Reviving traditional stone craftsmanship gained prominence given the focus on sustainability, cultural identity, and architectural authenticity. Although modern architecture mostly features traditional materials like concrete, glass, and steel, they pose significant environmental problems. With its low embodied energy, natural durability, and powerful cultural symbolism, stone presents an interesting substitute that deserves further study.

1.3 Aim

The primary aim of this research is to critically analyze how traditional Indian stone craftsmanship can be revitalized and integrated within contemporary architectural practices, emphasizing sustainability, cost-effectiveness, and technological innovation.

Research Questions

- How is traditional stone craftsmanship relevant and beneficial in contemporary architecture?
- How can modern technological interventions overcome traditional challenges associated with stone craftsmanship?

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- In what ways does integrating stone-craft contribute to cultural heritage and environmental sustainability in today's built environment?

1.4 Objectives

- To examine the historical and cultural significance of traditional Indian stone craft.
- To analyze how modern tools and design workflows can help scale and adapt traditional stone techniques for contemporary applications.
- To study real-world case studies that demonstrate the effective use of stone craftsmanship in sustainable and culturally rooted modern architecture.

2. LITERATURE REVIEW

Traditional Indian stone craftsmanship has long been an essential component in construction, serving both functional and symbolic purposes.

Among the most identifiable elements in Indo-Islamic specifically Mughal architecture are jali, or stone lattice screens. Designed mostly from sandstone or marble, jalis have both aesthetic and practical uses. They control airflow, filter strong sunlight, and provide seclusion; all the while, they create dynamic light and shadow play inside. Their design captures common knowledge—achieving thermal comfort without depending on synthetic cooling systems

Economic and Lifecycle Benefits

Although traditional stone work may have a larger upfront cost because of skilled labor and time, its long-term worth rests in durability and low upkeep. Often needing less frequent repairs or replacements than plaster, concrete, or steel finishes, natural stone ages elegantly, resists corrosion and weathering, and studies show that stone buildings are more cost-effective over a thirty-year lifetime since they require noticeably less maintenance and energy consumption *(Lundmark, 2020)*.

Stone also helps to increase property value; designed stone façades and detailing often become architectural highlights that draw cultural tourists or premium residential buyers, particularly in projects inspired by history *(Schrenk, n.d.)*.

2.1 Revival Through Technology

Technological interventions have started turning conventional stone methods into workable tools for modern design. Rapid prototyping and precision manufacture of jalis, carvings, and inlays have been made possible by CNC (Computer Numerical Control) machining, robotic carving arms, 3D modeling, and waterjet cutting. Complex geometries can now be created by designers using parametric software, then directly translated into stone *(Tazarvi & Tazarvi, 2025b)*.

Modern tools and techniques augment and enhance workability in traditional stone-craft that earlier took longer man-hours engaging older generations of craftsmen. The traditional craftsman can now focus on bettering design and finish instead. Luxury residences, institutional buildings, and cultural restoration projects may well be benefited with this advanced mix of traditional yet modern mix of craft and technology *(Tazarvi & Tazarvi, 2025b)*.

Companies like Sarga India and Traditional Stone Carvers of Rajasthan have worked with contemporary architects to create modular jali panels, digitally manufactured stone facades, and adaptive reuse elements for historic buildings.

3. COMPARATIVE ANALYSIS

The environmental and economic advantages of stone craftsmanship over more traditional materials are shown in great detail here.

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3.1 Environmental Advantages of Stone

- **Low Embodied Energy**: Minimal processing reduces energy consumption.
- **Thermal Efficiency**: Natural thermal mass reduces dependency on heating and cooling systems.
- **Durability**: Exceptionally long lifespan minimizes environmental impacts from replacements *(Schrenk, n.d.)*.

Criteria	Stone Craft	Modern Materials
Sustainability & Environmental Impact	Low embodied energy; minimal processing; natural thermal mass; recyclable and long-lasting.	High energy consumption during production; greater CO_2 emissions; may require frequent maintenance/ replacement.
Cost Factors	Upfront cost can be higher (especially for intricate work), but life-cycle costs are lower due to durability and minimal upkeep.	Often lower material cost due to mass production, but can incur higher long-term maintenance and replacement costs.
Architectural Value & Aesthetics	Unique, non uniform textures, cultural richness, and a sense of permanence & local identity.	Provides uniformity, scalability, and a modern, sleek aesthetic, but may lack warmth and distinct cultural narrative.
Structural Performance	Excellent in compression; fails in tension and bending unless reinforced by hybrid techniques.	Superior performance in tension and bending; engineered for high-rise and dynamic structural demands.
Potential Drawbacks	Heavy, labor-intensive, time-consuming; dependent on artisan skills; less standardization.	Can lead to over-engineered, impersonal designs; environmental costs; sometimes less durable in extreme climates.

Table 1: Comparative analysis between traditional stone craft & modern construction materials. (source: author)

3.2 Economic Benefits of Stone Craftsmanship

A 30-year lifecycle cost model and similar studies (Raja, 2018; GSJ 2025) comparing conventional materials and stone craftsmanship demonstrates clear advantages of stone. While stone has a higher initial cost, indicative in studies, its durability, low maintenance and above all low-carbon footprint can lead to long-term savings and ecological gains in terms of sustainability.

3.3 Stone Craftsmanship Integrated with Modern Technology: Advantages & Disadvantages

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Advantage	Description
Enhanced Precision	CNC machines and digital modeling tools allow for intricate stone carving with high accuracy.
Increased Efficiency	Technology significantly reduces time required for carving, cutting, and shaping stone elements.
Cost-Effective at Scale	While traditional hand carving is labor-intensive, mechanization lowers production costs for large projects.
Preservation of Craft	Technology helps scale traditional design motifs while artisans can focus on final finishes and artistic touches.
Design Innovation	Parametric and algorithmic design software expands what can be achieved in stone, including organic and complex forms.
Sustainability	Stone is naturally sustainable; pairing it with efficient fabrication tools minimizes waste and energy usage.
Structural Optimization	Post-tensioning, digital simulation, and hybrid systems improve the use of stone in load-bearing roles.

Table 2: Advantages of Stone Craftsmanship (source: author)

Disadvantage	Description
Loss of Artisan Identity	Excessive reliance on machines may result in loss of uniqueness or the "human touch" in designs.
High Initial Investment	CNC routers, 3D scanners, and stone milling machines are expensive and require skilled operators.
Skill Gap	Traditional artisans may not be trained in digital workflows, creating a disconnect between craft and tech.
Over-Standardization	Mass production can lead to repetitive and generic aesthetics, reducing the cultural richness.
Material Limitations	Not all stones are suitable for advanced fabrication due to hardness or fracture risks during high-speed machining.
Energy Use in Machines	Although stone is low in embodied energy, CNC machining still consumes electricity and may offset part of the sustainability gains.

Table 3: Disadvantages of Stone Craftsmanship (source: author)

4. CASE STUDIES FROM INDIA

New Indian Parliament Building, New Delhi

The New Indian Parliament exemplifies how traditional Indian aesthetics can be adapted to contemporary government architecture. A defining feature is the extensive use of **CNC-carved sandstone jali screens**—reminiscent of Mughal and Rajput architecture—that function not only as symbolic and decorative elements but also serve **passive environmental roles**, such as **solar shading, glare reduction, and natural ventilation**.

The jalis were manufactured using **computer-controlled machining for precision**, followed by **manual finishing by local artisans**, ensuring that **cultural authenticity** was retained. The modularity of the jali panels also allowed for faster on-site installation and ease of maintenance. This seamless combination of **digital fabrication with handcrafted detail** reflects India's aspirations to merge tradition with innovation in its democratic institutions.

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Fig 1: New Indian Parliament, Delhi (Source: Google Images)

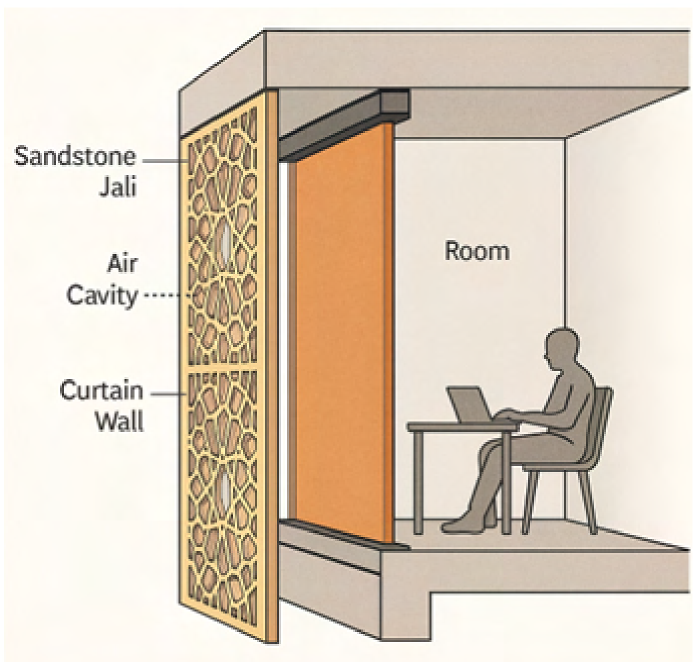

Fig 2: Sandstone Jaali Double-skin Facade (Source: AI Generated)

Krushi Bhawan, Bhubaneswar

Krushi Bhawan is a **government office for the Department of Agriculture**, whereby its architecture goes far beyond bureaucratic functionality. Designed by Studio Lotus, the building blends **vernacular architecture and sustainable design**, using **locally sourced laterite stone and terracotta**. The façade is adorned with **brick reliefs and tribal motifs**, created in collaboration with local artisans from Odisha, celebrating regional identity.

The stone detailing is more than ornamental—it aids **thermal insulation**, while the **courtyards and**

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shaded corridors promote **passive cooling**. The material palette responds to Bhubaneswar's hot and humid climate, and the **craft-based detailing** generates employment and community involvement. Krushi Bhawan stands as a symbol of **architecture rooted in people, place, and craft**.

Fig 3: Krushi Bhawan, Bhubaneshwar (Source: Google Images)

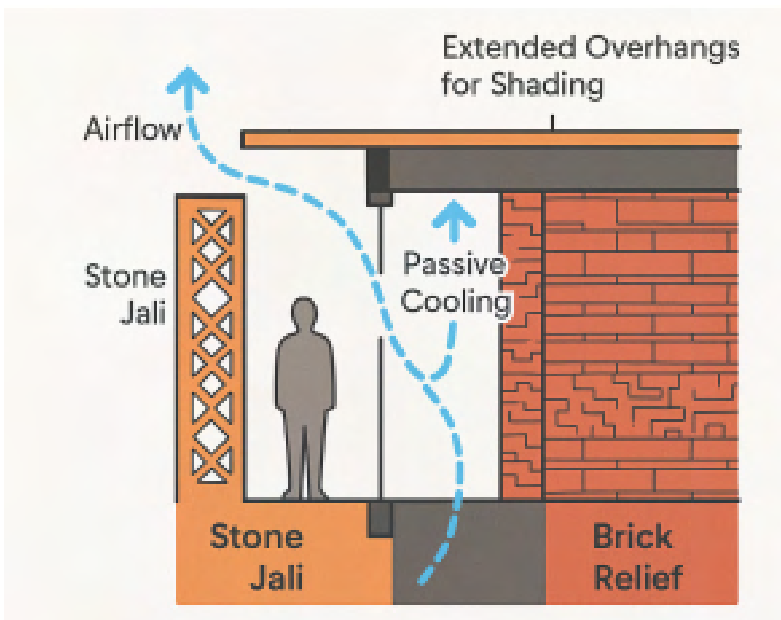

Fig 4: Passive Cooling with Stone Jaali and Brick Relief (Source: AI Generated)

Ganga Maki Studio, Dehradun

Located in the Himalayan foothills, Ganga Maki Studio by *Maki and Associates* is a unique cultural and artistic hub that **revives dry stone masonry** as a primary structural and aesthetic system. Using **locally sourced stone**, the structure is built with minimal cement or mortar, demonstrating both **ecological sensitivity** and **craftsmanship-led construction**.

The studio incorporates **thick stone walls**, which naturally **regulate indoor temperatures**, reducing the need for mechanical heating or cooling. This is particularly significant in Dehradun's composite climate. Rather than relying on industrial interventions, the project was **executed by skilled artisans** who used

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traditional joinery and hand tools, preserving knowledge that's becoming increasingly rare.

Ganga Maki Studio is a compelling example of how **craft-based architecture can be both low-carbon and architecturally refined**, offering a **model for rural and regional buildings** that value heritage, resilience, and sustainability.

Fig 5: Ganga Maki Studio, Dehradun (Source: Google Images)

Fig 6: Benefits of Thick Stone wall (Source: AI Generated)

5. FINDINGS AND CONCLUSION

Considering the facts, it is clear that stone craftsmanship is not just a nostalgic tribute to the past but also a futuristic solution that represents the values of sustainability, economics, and cultural richness in architecture.

When considered throughout the whole lifetime of a structure, stone shows to be structurally solid, environmentally friendly, aesthetically perfect, and reasonably affordable. From climate-responsive facades to luxury interiors and public buildings, current fabrication techniques have opened new possibilities for this historic material so it may satisfy the demands of modern architectural practices.

Real-world architectural examples all across India that have been presented here show not only theoretical models but also the practical viability of stone workmanship. These results demand a fresh emphasis on stone in architectural competitions, policy systems supporting vernacular and sustainable design, and

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curricula in education.

Stone becomes a better substitute for traditional materials as the building sector moves more and more toward circular economy ideas and low-carbon models since it offers both performance and poetry.

In essence, the research confirms that it is not only feasible but also imperative to revive and reimagine Indian stone work using contemporary technologies. It provides builders and designers with a timeless means to communicate modern ideas while being anchored in sustainability, cultural continuity, and legacy.

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ISBN 978-93-342-4408-3

SMART AND SUSTAINABLE CITIES (A Theoretical Framework)

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Abstract

The purpose of this paper is to conduct a theoretical & philosophical analysis of concepts, frameworks, models related to Smart & Sustainable cities to explore the strength, weakness, opportunity, threats in the process of the implementation.

Key Findings & Practical Implications of the study through SWOT analysis:

Tenure for project deliverables (& impact) for smart cities concepts are within 5 years & for sustainable cities 15-20 years. Humanity & planetary life is in danger if threats are not mitigated & weaknesses are not overcome. Developing countries must conduct their own SWOT in a local context before implementing successful concepts, models/frameworks borrowed from the developed countries. ***Conclusion:*** Smart City framework is a private sector growth accelerator to improve quality of life of communities. Sustainable city development is a public sector global initiative to improve overall livability index, attain sectoral growth & balance in a larger context.

1.1 Introduction

We are in the era of Anthropocene. Industrial Revolution 4.0 in the construction industry has been propelled through IoT and related technologies relevant to Planning, Designing & Project Management. The term Smart Cities is synonymous with Technology (Digital & Intelligent City) & the term Sustainable Cities are synonymous with Eco-friendly Cities & Communities that balances social, economic & environmental well-being for future generations.

Key Words: Smart Cities, Sustainable Cities, Sustainable Development Goals, Circular Economy, Architectural Planning, Urban Planning, Innovative Approach, Resilient Built Environments.

1.2 Scope:

The scope of this paper is limited to literature studies, theoretical queries.

1.3 Methodology (A theoretical framework will be employed, encompassing the following components)

i. Framing research questions to understand smart & sustainable cities.
ii. Literature review of relevant concepts & theories to explore research questions. Case study of projects implemented with success stories.
iii. Critical analysis & summarizing findings with concluding statement.

1.4 Research Questions

i. What are the concepts & theories of smart cities & sustainable cities?
ii. What are the strengths, weaknesses, opportunities & threats in context of the concepts & theories of smart cities & sustainable cities?
iii. How can the principles of smart cities and sustainable cities be developed parallelly or be integrated to foster wholistic development, promoting planetary well-being and the progress of human civilization also?

2. 0 The Study and Research Summary:

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Examining the philosophies, concepts, definitions & theories has brought forth commonalities and differences in the idea of Smart City and Sustainable city**. Commonalities** are in the theories and practice of addressing the concerns to resolve the Infrastructure Issues, Economic Stability & Climate Change. **Differences** are rooted in conceptual philosophies**. [1(a-f)]**

2.1 Frame Works & Strategies:

These have been analyzed across Four Criteria: Conceptual, Foundational, Structural, Functional. Conclusions have been drawn for Common aspects & Differences as follows: **[2 – 4]**

Commonalities of FrameWork / Strategies		**Difference of Frame Work / Strategies**	
Smart City	Sustainable City	Smart City	Sustainable City
Conceptual		**Conceptual**	
Energy Efficiencies, Climate Change Issues, Industries, Economies, Communities, Prosperity		National Localized Agenda National Localized Funding	Globalized Agenda Global Funding Assistance
Foundational: (Environment & Climate)		**Foundational**	
Energy Efficiency to Mitigate Climate Change	UN Programs for Environment & Climate	Industrial Revolution 3.0 Private Sector Intrgration in Public Sector Agenda	MDG 2000/ SDG 2015, SDG 11
Structural: (Circularity)		**Structural:**	
Technology Intensive for energy efficiency & achieve circular economy	Circular strategies for resource material regeneration concepts	City Specific deliverables & Indicators	Defined common global parameters, variables & indicators
Functional (Technology Dependent)		**Functional**	
Use of technology for data collection, analysis & monitoring with help of government &private entities		Monitoring through local anthorities (ICCC), Chambers of commerce, private service providers communities etc.	UN Statistical commission larger monitoring umbrella for indicators, coordinated with regional players.

Table 1. "Framework & Strategy Analysis" (Credits: Author)

<u>3.0 Case Studies of:</u>

Smart City Models & Pilot Projects: In depth analysis of strategies adopted by Smart Cities which are successful in achieving their objectives through have been done by study of "solutions deployed" and "success factors" contributing to achieving the goals by the cities mentioned. **Table 2: Ref [5]**

	Amsterdam	**Barcelona**	**Helsinki**
Smart City Initiatives Covered	Citadel, Common4EU, NICE, Digital Cities and Open Cities.	Fireball, Opencities, Icity, Commons4eu, Citysdk, open-dai) Co-	NiCE, innovative and sustainable urban development policies'.

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		operates metropolis, euro cities, covenant of mayors, world e-gov org	
Solutions Deployed	Climate Street, Ship to Grid, Smart Building Management System, Health Lab	Control Of Lighting Zones, Smart Parking, Smart & Sustainable Architecture, E-gov.	Digital services, mobile applications and open data services
	Amsterdam	**Barcelona**	**Helsinki**
	Climate Street Goals Sustainable Waste Logistics, energy displays, LED lighting, Smart Meters, Energy Management Systems. **Success Factor:** Partnership with Local Business Association	Smart Parking: Wireless parking ease city traffic by showing free parking spaces. Info sent to a data center for smart phones sending real-time data to users. System guides the driver to the nearest parking spot. **Success Factors:** Mobile Apps.	**Digital services** Public-private partnerships in dev of new urban digital services. **Success Factors:** Collaboration with the private sector, municipality, public sector and residents.
	Ship to Grid Goals Project allows inland ships in the harbor of Amsterdam to use green energy from the grid instead of their own stationary diesel generators. This reduces CO_2 emissions and leads to less noise and air pollution **Success factor:** Industry Collaboration	**Control Of Lighting Zone:** Information sent to central control center. Control from Public spaces to monitor, receive alerts and manage from this single point. Sensors can adjust lighting depending on the time of day and the presence of people. Energy savings of 40-60% reducing CO_2 emissions. It is also an investment in R&D and innovation **Success factor:** Industry Collaboration	**Mobile applications:** In 2009 the Helsinki Region Transport Authority opened up all its data, leading approx 50 mobile applications by developers to serve diff needs & create value for commuters and travelers. These new services contribute to decreasing traffic congestion & mitigating negative env impacts of the Helsinki traffic system. **Success factors:** Public Participation.

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Smart Building Management System Automation of the smart switch (central control) plugs, with switching off lighting and appliances outside office hours reduced electricity consumption by 18%. Implemented For entire Business Street. **Success factor:** Office Space Owner community collaboration	**Special Mention:** Smart City Of Amsterdam Health Lab Enabling elderly people to live longer in their own (smart) house. was centered on real value creation for healthcare users in their own local context and for their own needs. **Success Factor:** The use of a multidisciplinary team and end-user involvement in the process of solution development.	**Smart & Sustainable Architecture. Media-tic Building:** 300 sensors for human presence, artificial light levels, the building has a distributed intelligent system For the facade cushions as well. 114 tons of green house gas émission per year reduction. **Success Factors:** Public & Private Sectors, Industry Collaborators.	**Open Data Services** In July 2013, over 1,030 databases were available at the website, covering a wide mnge of urban phenomena, such as living conditions, employment. transport, economics and well-being. Geo-referenced, geographic information system data are well represented in this dataset **Success Factors**: PPP

Table 2: Smart City Case Study Analysis (Source: Author)

4.0 SWOT Analysis & Key Findings

Based on study of Frameworks, Strategies, Case Studies, and philosophical query of the concepts **Ref: [1-5 , 6, 7]**

SMART CITY	**SUSTAINABLE CITY**
Strength	
✓ Conceptual ideas are well defined. ✓ Speed & efficiency of implementation in context of Time, Area Covered, Population Covered is more. ✓ Tasks considered as occupational hazard to humans can be done with help of technology imparting dignity of labor in construction industry as well as infrastructure maintenance. ✓ Care takers in field of health can be aided for physically & Mentally challenged patients. ✓ Expenditure & Returns is predictable as dependent on tangible resources.	✓ Concepts & Strategies both are well defined ✓ Best Practices have global consensus with tested Pilot Project & Case Studies. ✓ Flexibility in Planning & Designing as models have to adapt to existing local and geographical & environmental conditions encouraging Individuality. ✓ Communities directly involved in managing habitats. ✓ Direct impact on SDG's indicators of circularity & environmental impacts. ✓ Direct contribution in Regeneration of Natural Resources and safeguarding Intangible Resources.
Weakness	
✓ Practical Implications of Strategies For data (collection, storage, integrity, accuracy, confidentiality) is not well defined with global	✓ Project success is influenced by Political, Economical, geographical constraints as projects are land based and resources may lie in other city or countries.

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consensus for developers & users but data is shared globally indiscriminately. ✓ Legalities & Acts related to data transparency, Right to Information Act V/s Legalities & Acts related to Privacy, dignity, Security, Intellectual property rights, trade & commerce not well defined with Global Consensus. ✓ Duplication of data. Backup data is essential in case of total city wide outage & natural calamity. ✓ Seamless transition & Integration of analog to automated systems during emergency.	✓ Takes longer time for project implementation as dependent on Tangible & Intangible Resources so high Risk to Insure or loan through private lenders. ✓ Project Success & outcome are intangible qualitative aspects linked to environmental criteria & improved Human Development Index ✓ verification & validation of data inputs may take longer time when Coverage area & population is larger or scattered ✓ Integration Of Smart Monitoring/Maintenance aspects needs to well defined with political and community consensus.
Opportunities	
Improved City Governance & Management ✓ Faster, efficient implementation & acceptability in industries & commerce due to Automation. ✓ Returns are tangible and quantifiable hence insurable business opportunities. ✓ Outcomes are Specific, Measurable, Achievable, Relevant, Time-bound so Lenders & Borrowers are on a clear negotiable ground. ✓ SMART Cities have clear and actionable goals which can be integrated with project management tools so contracts are negotiable with less risk. ✓ Technology based Mobility, Accessibility, Resilience, Technology with SMART Systems can have self regulated pricing systems for transportation and other chargeable amenities..	**Improved Quality Of Life** ✓ Trade-Commerce & economical opportunity through Circularity & Circular Economy owing to replicable strategies. ✓ CSR-Corporate Social Responsibility. Save the unique ecosystem of Planet through natural & sustainable systems and initiatives. ✓ Social, Mobile, Analytics, Real-time, Transformative outcomes ✓ Eco-tourism: Different models (responding to local conditions) encourage tourism as people choose different & local experiences over standardized global monotony of service industry. ✓ Improved Land-values and development regulations for brownfield zones. ✓ Increased options for material resources due to circularity.
Threats	
✓ Future Implications for resources such as are earth elements depletion. ✓ Laws regarding Dark web, Digital currency digital arrest, biased algorithms not defined. ✓ Motor & cognitive Skills deterioration with more dependence on technology. ✓ Lack of E - waste disposal policies & implementation ✓ Threats arising due to Technology based resources like radiation & Pollution ✓ Natural Environment & Planetary Destruction due to excessive use of water for data centers.	✓ Natural disasters make project out come unpredictable as success depends on Natural elements, climate, weather. ✓ Loss of forests (when no reforestation) if replacing concrete with timber or in favor of commercial agriculture. ✓ Threats arising due to integration of technology in sustainable strategies (Radiations/pollution) ✓ Sustainable Materials materials like Sand & Clay for construction industry is losing ground owing to Env Degradation.

(Ref: https://scitechdaily.com/earth-tilted-weve-pumped-so-much-groundwater-that-earths-spin-shifted/?expand_article=1)	✓ Excessive extraction & use of ground water resources for agriculture (Ref: Ref: https://scitechdaily.com/earth-tilted-weve-pumped-so-much-groundwater-that-earths-spin-shifted/?expand_article=1)

Table 3: SWOT Analysis: Credits : Author Ar Sangita Mohanty

5.0 Practical Implications

Study & analysis are thought to provoke for national interest in context of Smart Cities & Alarming in context of Sustainability. From the study, it can be summarized that "A City Is as Smart As it's People (Human Resource) & as Sustainable as the Tangible & Intangible resources There In" *(Quote) Ar Sangita Mohanty*). Government of India has invested ₹1.47 lakh crore in the 100 Smart Cities Mission as of December 2024. To achieve benefits of SDG11 the complexities of Tangible & Intangible resources need to be gauged before implementation of the projects. As it is about Finances & Job creations. It is about investing in priorities. It is about managing the given time frame. It is about Human resources, skills, job creation to manage & implement the new concepts / strategies / planning. It is about Natural Resources (Raw material / Recycled Materials/ Circular economy) It is about dealing with the new set of problems which comes with any new Concept / philosophy. Hence concepts / ideas / models / strategies should be processed through SWOT analysis to guide us in strategizing future projects as applicable for local context and developing countries. **Ref: [6, 7]**

6.0 Value of Study & Conclusions:

Value of the study is in identifying the Fact (through critical review) that both Concepts of Smart & Sustainable cities can be collaborative as have been successfully demonstrated in **Ref [9]** Singapore & EU models **Ref: [4,5]**. **In conclusion and** addressing the final research question: (**As discussed in 1.4 (iii) above)** Wholistic development of Smart & Sustainable concepts can be collaborative when *the Weaknesses & Threats as identified in (table 3 above) SWOT Analysis are addressed.* **Weaknesses** can be overcome through frameworks such as **circular economy which is a win -win situation for** environment & sustainability as well as the economy, **Ref [8]. Threats can be** overcome by including **resilient strategies in planning of preparedness & response** for built as well as natural environment **Ref: [6,7]. My further queries** would be exploring concepts of Circular Economy, Eco-Cities, Walkable Cities, Urban Village which have common values of both Smart & Sustainable **Ref: [10]**

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"TRANSIT UNDER PRESSURE: Architectural solutions to crowd dynamics at Indian railway stations with a focus on the recent stampede at New Delhi Railway Station"

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Abstract

With an emphasis on the recent stampede at New Delhi Railway Station, this paper examines crowd control management at Indian railway stations and highlights the risks associated with extreme congestion brought on by large passenger volumes, antiquated infrastructure, and uncontrolled movement patterns. To ascertain the root causes of overcrowding, it examines crowd behaviour, station layout, and operational inefficiencies in addition to identifying critical infrastructure and emergency response flaws that fuelled the incident. Based on an analysis of global best practices in station design and management, the report recommends architectural interventions such as improved circulation pathways, restricted access and departure points, designated waiting zones, and clearly defined emergency escape routes.

Keywords: *Crowd dynamics, stampede prevention, railway stations, architectural interventions, pedestrian flow, emergency evacuation, spatial planning, wayfinding, Indian Railways, smart surveillance.*

1. INTRODUCTION

Railway stations and other public transportation hubs are essential for urban mobility, but crowd safety issues are becoming a bigger problem. Station architecture frequently falls behind contemporary requirements in India, a country with very high passenger volumes. In order to frame architecture as a strategic instrument for regulating human mobility rather than merely a structural solution, this study presents the crucial relationship between crowd behavior and spatial design. By prioritizing user safety and real-time adaptation in design choices, the study seeks to redefine station planning.

Overview of the New Delhi Railway Station Stampede (February 15, 2025) Incident

The most recent stampede in the New Delhi Railway Station was a tragedy which highlighted the serious crowd control and station infrastructural flaw. It occurred when there was a sudden ingress of passengers who were endeavouring to move through jam-packed egresses and platforms, resulting in panic, confusion, and uncontrolled movement.

Key Factors Contributing to the Stampede:

- A high influx of passengers due to delayed trains and peak-hour congestion.
- Limited space for movement, causing bottlenecks at platforms and staircases.
- Confusing circulation paths and lack of clear signage led to passengers pushing against one another.
- Misinformation and fear may trigger a mass rush, worsening the situation.
- Delayed intervention by authorities and lack of predefined evacuation routes.

CROWD DYNAMICS IN RAILWAY STATIONS:

Train station crowds display unique behavioural patterns impacted by social dynamics, space limitations, and urgency. Herd behaviour, in which people follow others instead of making their own decisions, is ubiquitous and frequently causes traffic jams at platforms, ticket desks, and entry/exit points, particularly during emergencies or train arrivals. Panic reactions in emergency situations can lead to illogical behaviour, stampedes, and mayhem, which are made worse by inadequate signage, a lack of emergency infrastructure, and a lack of supervision.

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Sequence of events:

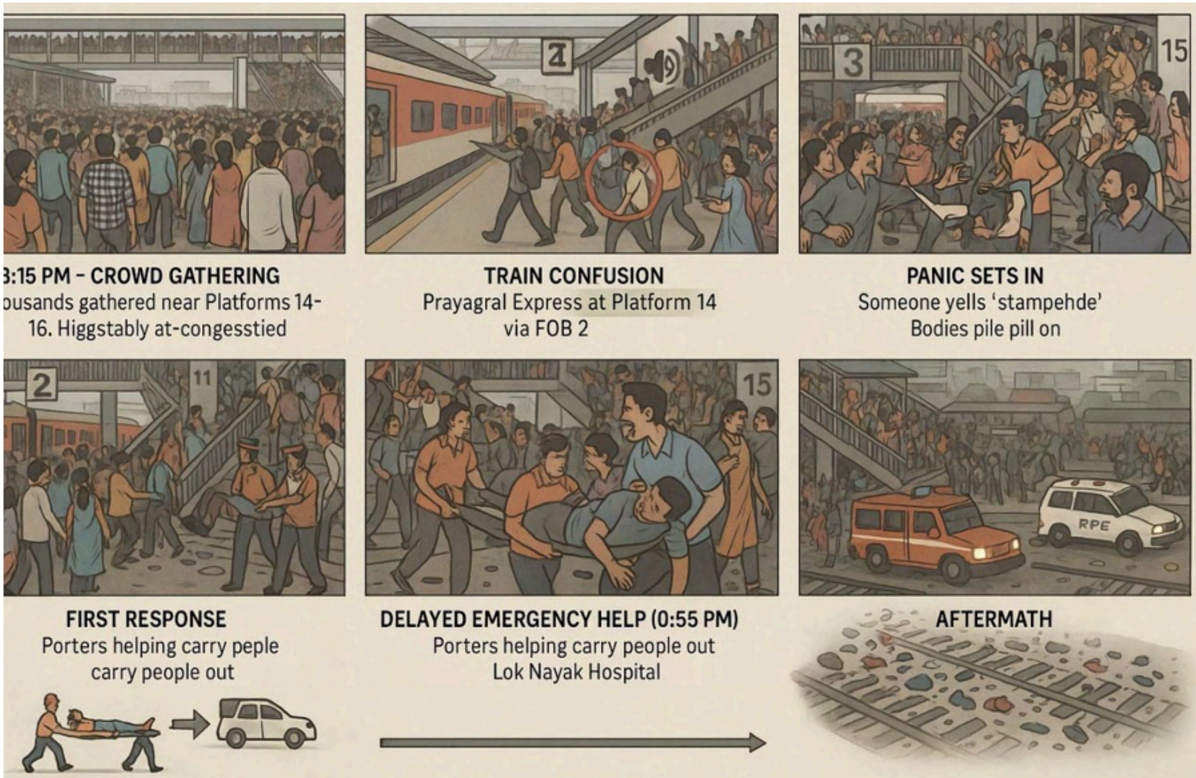

Fig 1-Storyboard explaining the series of events of the New Delhi Railway Station Stampede (February 15, 2025) Incident (Image- AI generated)

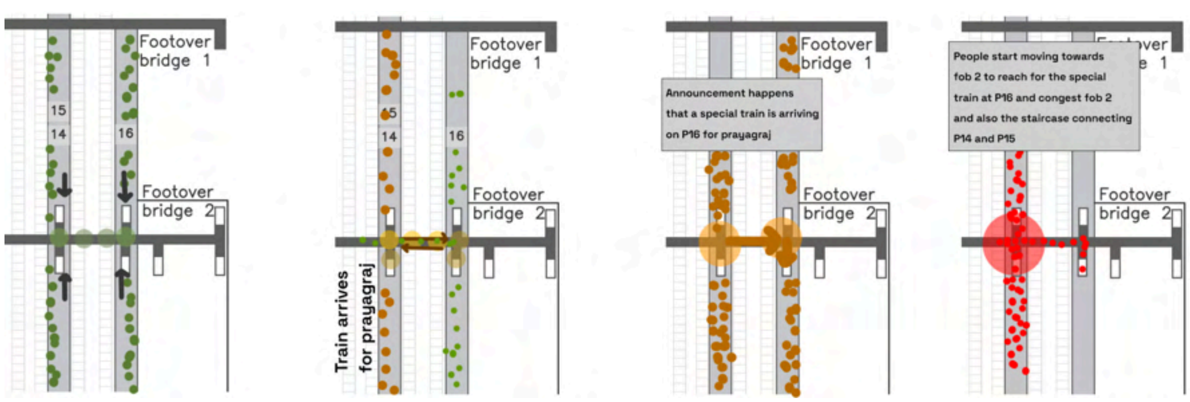

Fig 2-Conceptual depiction of crowd movement during the New Delhi Railway Station Stampede (February 15, 2025) Incident in context of Plan of Railway station. (Image by authors)

Station dynamics are further impacted by various crowd types: daily commuters move quickly because they are accustomed to the area, but they also add to peak-hour congestion; tourists and infrequent travellers move slowly and stop frequently because they are unfamiliar with the area, disrupting flow; and vendors or unofficial activities encroach on circulation zones, resulting in obstructions. It is critical to comprehend movement psychology since people tend to take the quickest way, which frequently results in choke points, and confined areas heighten pressure and haste. In order to control flow and reduce hazards in crowded areas, it is essential to strategically employ signage, visual signals, and guided pathways.

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2. CAUSES AND TRIGGERS OF CONGESTION IN RAILWAY STATIONS IN INDIA:

India's railway stations are extremely dynamic places that are prone to congestion because of a complex interaction between operational inefficiencies, human behaviour, infrastructural constraints, and outside influences. Smooth passenger flow is severely hampered by infrastructure-related problems such inadequate platform space, badly planned entry and departure locations, inadequate escalators, bridges, and staircases, imprecise signs, and pervasive encroachments by unofficial vendors. Congestion is made worse during peak hours by operational issues such as conflicting train timetables, delays at security and ticketing checkpoints, understaffed crowd control teams, and disorganized boarding and deboarding procedures.

The issue is exacerbated by human and behavioural variables such as panic in high-density places, herd mentality, inattention, disregard for movement regulations, and extended passenger stays, particularly when crowd flow is disturbed close to platforms, exits, or waiting areas.

Unexpected and uncontrollable passenger surges are frequently caused by outside factors including severe weather, holiday and celebration rushes, transportation strikes, and unique occasions like religious pilgrimages or political rallies. The possibility of overcrowding and associated dangers, such as stampedes, is further increased by inadequate emergency evacuation planning, a lack of real-time crowd monitoring, and antiquated infrastructure that cannot keep up with contemporary transit demands. In order to maintain passenger safety and operating efficiency, robust design and crowd control measures require a comprehensive understanding of these reasons.

3. CASE STUDY SUMMARY:

The comparative analysis of case studies performed by the authors examines two railway stations of India- **New Delhi Railway Station (NDLS)** and **Rani Kamlapati Railway Station (RKMP)**. Despite the significant contrast in **daily footfall**, **number of platforms**, and **train operations**, both stations serve as important nodes within India's railway network and present valuable insights into infrastructure planning, passenger flow, and design strategies.

NDLS, one of the busiest stations in India, handles a massive volume of passengers and trains daily, while RKMP represents a modern, redeveloped station with a focus on efficiency, inclusivity, and passenger comfort. By comparing these two typologies **a legacy high-traffic hub** and a **new-age benchmark facility** this study aims to highlight critical design and operational factors that impact user experience, circulation, safety, and accessibility.

The analysis identifies areas where high-traffic stations like NDLS can improve by adopting best practices from newer models like RKMP, thus informing future upgrades, retrofits, and station redesigns across the country.

Table-1 Comparative analysis of New Delhi Railway Station (NDLS) and Rani Kamlapati Railway Station, Bhopal (RKMP)

Parameter	New Delhi Railway Station NDLS	Rani Kamlapati Railway Station RKMP
Daily Footfall	Approx. **500,000** passengers	Approx. **60,000** passengers
Train Movements (Total)	**279** trains (106 halting, 87 originating, 86 terminating)	Approx. **50–60** train movements
Approach to Crowd Management	**Reactive**: police ropes, manual barricades, temporary crowd segregation on platforms	**Proactive**: designed flow zoning, predictive routing, and automated systems
Infrastructure Readiness	Narrow FOBs, uneven stair risers, limited escalators/elevators; crowd surges unmanaged	Wide FOBs with direction-based flow, well-distributed vertical circulation (stairs, escalators, lifts)

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Technology Integration	Limited: CCTV and static signage; no real-time crowd monitoring or digital alerts	High: real-time crowd density monitoring, digital signage, automated gates
Platform Management	Rope-based division into walking & waiting zones only on select high-traffic platforms (e.g., 12, 16)	Zoned platform areas, wide coverage shelters, vending zones separated from boarding areas
Flow Segregation	No clear separation of arrival vs. departure passengers; frequent counterflows	Complete segregation of arrival and departure paths with radial circulation
Safety Systems	Manual crowd control, small signage, limited panic/emergency mechanisms	Emergency call buttons, fire exits, digital alerts, CCTV-based passive surveillance
Effectiveness in Peak Hours	High risk of bottlenecks and stampede-like conditions	Smooth passenger dispersal and minimal choke points due to layered circulation design

4.1 Crowd Management: A Comparative Overview of conducted case studies

At the New Delhi Railway Station (NDLS), crowd control is mostly reactive and primarily dependent on physical interventions like ropes, temporary signage, and police barricading. The station is frequently overcrowded, particularly at foot overbridges (FOBs), platform access points, and entry gates, due to its more than 500,000 passengers per day and more than 250 train movements (including originating, halting, and terminating trains). Confusion and bottlenecks are common when dynamic routing, real-time crowd monitoring technologies, and distinct pedestrian segregation are lacking. Although they provide short-term respite, recent solutions such employing ropes to separate platforms into mobile and immobile zones are not systemically scalable.

Rani Kamlapati Railway Station (RKMP), on the other hand, exhibits a proactive and technologically advanced approach to crowd control. RKMP employs zonal circulation, automated entry systems, digital signage, and real-time crowd flow monitoring to guarantee seamless mobility around the facility, even with a more moderate daily passenger volume of about 60,000.

Congestion is lessened even during peak hours when arrival and exit flows are clearly separated and there are broad concourses, escalators, and elevators. RKMP's design is predictive, guaranteeing safety and comfort without depending on harsh or constrictive measures, in contrast to NDLS, where informal and ad hoc interventions are typical.

Fig 3- Left- Multiple images showing large crowd surges at both entries, especially at the Ajmeri Gate during morning rush, with minimal wayfinding (NDLS), Right- Images showing queue lines, directional floor patterns, open circulation cores, and unused corners remaining clear (RKMP).

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Fig 4- Left- Image showing uneven crowd distribution on platforms, broken tactile and overcrowded waiting areas (NDLS), Right- Image showing tactile paths, clean shelters, managed & segregated crowd movement (RKMP)

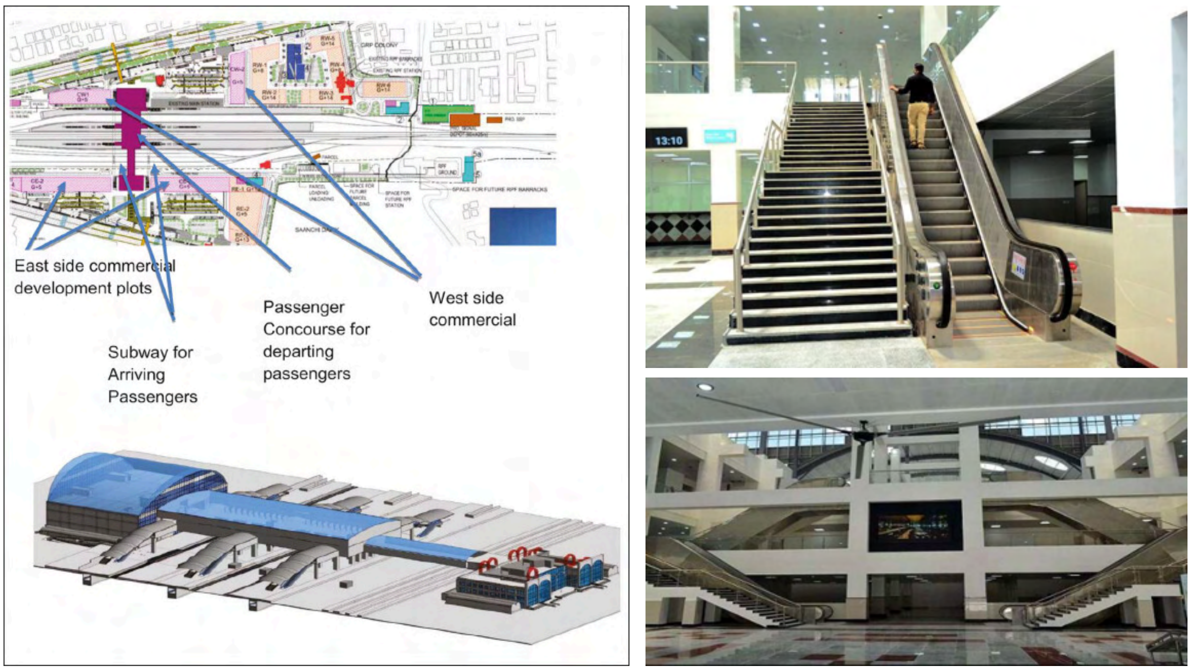

Fig 5- Left- Image showing separate passenger concourse for arrival and departure (RKMP Station), Right- Image showing clear and comfortable vertical circulation at RKMP Station.

5. PLANNING AND DESIGN STRATEGIES BASED ON LITERATURE REVIEW AND CASE STUDIES:

- **Spatial Planning-** Effective crowd control starts with clear zoning—separating arrival, departure, ticketing, and security areas. One-way loops reduce cross-traffic, while spill buffers near bottlenecks manage surges. Sequential spatial layouts support orderly movement.
- **Vertical & Horizontal Circulation-** Vertical stacking (e.g., arrivals below, departures above) distributes load across levels. Regularly spaced wide staircases and escalators prevent choke points, and bridges or underpasses maintain uninterrupted flow between platforms.
- **Wayfinding & Visual Cues-** A clear signage hierarchy (primary, secondary, emergency) aids navigation. Flooring textures, colours, and digital displays subtly guide movement and adapt during congestion or emergencies.
- **Materiality & Safety-**Tactile and grooved surfaces assist navigation and zone definition. Fire-safe, anti-slip, and glare-free materials enhance safety and comfort under both normal and emergency conditions.

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- **Smart & Responsive Systems-**Sensors and automated gates adjust flow in real time. AI tools support predictive crowd modelling, while kiosks and digital aids assist in navigation and crisis management.
- **Emergency Crowd Control-** Design must prioritize short, direct escape routes, visible exits, and fire zoning. Smoke control, refuge zones, and structurally robust paths reduce risks. Backup lighting, photoluminescent markings, and dual power ensure safe evacuation.
- **Cultural & Contextual Adaptations-**In India, informal queuing and high crowd tolerance require flexible layouts. Passive design tools like steps, screens, benches that help manage flow. Gender-inclusive zones, multilingual signage, and accessible features ensure equity and usability.

6. FEASIBLE ARCHITECTURAL INTERVENTIONS

Based on observations and case study analysis, the following architectural interventions are proposed to enhance crowd safety and flow at Indian railway stations. These are divided into retrofit-based (low-cost, implementable within existing infrastructure) and reconstruction-based (long-term, structural improvements).

A. Retrofit-Based Interventions (Low-Cost, Immediate Impact)

These strategies can be added without major construction, focusing on improving spatial legibility and managing flow.

- Tactile and color-coded flooring (e.g., red for exits, blue for platforms) can guide crowd movement, inspired by airport systems.
- Modular physical barriers like steel barricades and queue managers help create temporary zones during peak hours.
- Improved lighting and bilingual, backlit signage, along with LED floor strips, increase visibility even in dense crowds.
- Anti-loitering benches in circulation zones discourage long-term sitting while designated seating areas remain accessible.
- Partitioned shelter pods made of recycled materials offer rest space for the homeless without obstructing flow. Digital crowd monitoring boards integrated with CCTV and PA systems provide real-time data to both authorities and users.

Fig. 5. Tactile & Textured Wayfinding Paths B. Zoning with physical barriers C. Lighting + Signage enhancements

B. Reconstruction-Based Interventions (Long-Term, High-Impact)

These require structural redesigns but ensure systemic improvements.

- Foot Over Bridges (FOBs) must be widened (minimum 5.5-6m), with separate lanes for uni-directional movement using markings and bollards.

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- Multi-level vertical circulation hubs combining elevators, escalators, and stairs should be placed at both ends of platforms, connecting directly to other transport modes.
- Where space permits, underground pedestrian subways can offload surface-level congestion, provided they are well-lit, ventilated, and monitored.
- Off-platform integrated waiting lounges, like airport-style holding areas, can control platform access and reduce idle crowds.
- Lastly, elevated police and emergency control nodes with 360° views, mic systems, and panic buttons offer command points for real-time monitoring and intervention.

7. CONCLUSION:

This paper contends that architecture plays an active role in ensuring crowd safety within public transit environments. According to this article, architecture actively contributes to crowd safety in public transportation settings. Indian train stations need to change from chaotic transit hubs to easily passable, people-centred areas. The suggested interventions such as circulation towers, enhanced footbridges, real-time signage, and tactile flooring are realistic and contextually sound.

The authors stress that controlling unpredictable crowds is as much a behavioural and policy issue as it is a design one, even though they acknowledge the study's narrow focus. This work provides a simple yet practical framework for future transit infrastructure by rephrasing the problem in terms of architectural methods. Instead, then continuing to represent systemic failure, the stampede at the New Delhi Railway Station ought to inspire a reconsideration of public space design. Given that safety design must continue to be dynamic and sensitive to changing urban circumstances, this study encourages more interdisciplinary discussion.

General Acknowledgement: "AI-based tools were used for storyboard image generation and for the refinement of text. All final content was reviewed and verified by the authors."

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ISBN 978-93-342-4408-3

Transition Spaces and Edges in Landscape Architecture

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ABSTRACT

In contemporary landscape architecture, transition spaces and edges are gaining importance as key spatial and ecological assets. These interstitial zones—thresholds, corridors, buffers—mediate between the built and natural environment, fostering connections across ecological, social, and aesthetic dimensions. Edges are no longer seen as static boundaries but as porous interfaces that actively shape the user experience and environmental functionality.

This research explores how innovative design and planning strategies can transform these overlooked zones into integrated systems of sustainability and expression, offering new paradigms in spatial thinking and landscape practice. Transition spaces and edges in landscape architecture are pivotal to how we experience, navigate, and understand outdoor environments. These in-between zones are not passive connectors but active, meaningful spaces with the potential to enhance ecological resilience, spatial identity, and human experience. This research focuses on how transition zones and edge conditions, when deliberately designed, can be transformed into rich, performative spaces that bridge innovation, sustainability, and design thinking.

The idea is rooted in both historical and contemporary perspectives. Thinkers like Jay Appleton, with his "Prospect-Refuge" theory, emphasized the importance of edges in offering psychological comfort and navigational clarity. Frederick Law Olmsted, in his park designs, masterfully manipulated edges and transitions to lead visitors gently from urban stress into natural calm. Similarly, Mohammed Shaheer's work on landscape transitions in Indian public spaces created cultural continuity between built structures and ecological elements.

Contemporary urban practices across Japan and Singapore extend this philosophy into vertical space—using building terraces, facades, and podium edges as new landscapes. These cities demonstrate how productive transition spaces, like elevated vegetable gardens and green corridors, serve as ecological and cultural interfaces between nature and the built environment. These global examples reinforce the evolving role of transition zones from passive thresholds to dynamic, adaptive landscapes.

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Figure 1. Prospect-refuge theory, rooted in evolutionary psychology, suggests that humans are instinctively drawn to environments that offer both a sense of security (refuge) and the ability to observe their surroundings (prospect). This preference stems from early human survival needs, where finding a safe place to hide while also being able to monitor for threats or resources was crucial. We see the best Restaurants and VIP Residences on prominent edges such as mountaintops and beachfronts.

GOALS:

- **Redefine transition spaces and edges** as spatial opportunities rather than neutral zones.
- Investigate the **ecological and social performance** of transitional design in various contexts.
- Create a design and assessment **framework/toolkit** that guides architects and planners.
- **Integrate lessons from renowned landscape architects** into contemporary practice.

SPECIFICATIONS

Typological Analysis:

- Linear transitions (e.g., paths, promenades)
- Nodal transitions (e.g., plazas, courtyards)
- Layered edges (e.g., riparian buffers, forest margins)

Edge Conditions:

- Hard vs. Soft edges (built walls vs. planted transitions)
- Visible vs. Invisible transitions (fenced vs. implied space shifts)
- Active vs. Passive use (market zones vs. contemplative paths)

Design Metrics:

- **Ecological:** Biodiversity support, water management, climate regulation
- **Social:** Accessibility, inclusiveness, comfort, place attachment
- **Aesthetic:** Sensory layering, visual rhythm, cultural symbolism

Influences from Practice:

- **Frank Lloyd Wright's Fallingwater** demonstrates the seamless blending of structure and site—its thresholds dissolve between interior and exterior.

Figure 2. Fallingwater's structure seamlessly integrated with woodland and water.

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- **Mohammed Shaheer's Sanskriti Kendra Complex in Delhi** offers a tactile example of courtyard-edge transitions that foster pause, play, and discovery. The entrance threshold is celebrated by a huge Banyan tree.

Figure 3. Sanskriti Kendra Complex transitions by Mohammed Shaheer.

- **Mohammed Shaheer's Sunder Nursery in New Delhi** showcases thoughtful layering of natural and cultural elements along its transition spaces, blending ecological restoration with sensory public engagement.

Figure 4. Sunder Nursery's multi-layered transition spaces integrating nature and heritage.

- **Frederick Law Olmsted's Central Park** uses open meadows framed by tree canopies to create transitions between city noise and green refuge.

Figure 5. Central Park's canopy-framed edge transitioning between city and green space.

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- **High Line, NYC** turns an elevated rail track into a biodiverse linear park, creating spatial transitions above the street. Designed by Landscape architecture firm James Corner Field Operations; design studio Diller Scofidio + Renfro; and planting designer Piet Oudolf.

Figure 6. High Line adaptive reuse of a former rail line as a linear transition zone.

Contemporary Global Practices: Edible Landscapes on Vertical Edges

In response to urban densification and the need for sustainable food systems, contemporary landscape architecture firms in Japan and Singapore are reimagining building edges as productive green infrastructure. No longer limited to ground planes, transition zones now ascend vertically—appearing on terraces, facades, podiums, and rooftop edges as vegetable gardens and micro-farms

- In Singapore, landscape urbanism is closely tied to its "City in a Garden" vision. Projects like CapitaSpring by Bjarke Ingels Group and RSP Architects feature elevated urban farms at terrace levels, integrating herbs and edible plants within recreational landscapes for office workers and residents. These productive edges enhance building thermal comfort, food access, and user engagement.

Figure 7. Elevated vegetable terrace integrating edible landscapes on building edges (CapitaSpring, Singapore).

- In Japan, firms like Toyo Ito & Associates and SANAA have collaborated with horticulturists to integrate vegetable beds and rice terraces along stepped building sections and community rooftops. These designs draw from traditional satoyama (mountain-edge farming culture), turning the act of

ISBN 978-93-342-4408-3

gardening into a shared spatial ritual that blurs the lines between public and private, nature and architecture.

Figure 8. Green walls and indoor farming at Pasona Urban Farm, Tokyo.

These practices redefine transition spaces as multi-sensory, living edges—offering ecological services (like pollinator support), educational engagement, and therapeutic benefit. They also embody prospect-refuge principles—with green elevation edges providing soft refuge and open views simultaneously.

METHODOLOGY AND MILESTONES

A. **Literature Review:** Study theoretical constructs such as Appleton's spatial psychology, landscape urbanism, and spatial justice.
B. **Case Studies:** Analyze five sites where edge and transition spaces redefine landscape identity (e.g., Cheonggyecheon Stream, Sanskriti Kendra Complex, High Line NYC, Sunder Nursery).
C. **User Behavior Mapping:** Conduct observational and participatory research to understand how people engage with these zones.
D. **Framework Development:** Synthesize findings into a design toolkit with diagrams and checklists for assessing transitional landscape quality.
E. **Application:** Propose a conceptual landscape design for a public urban edge (e.g., a metro station buffer zone or a riparian city edge).

CONCLUSION

The research reinforces the argument that transitional spaces and edge conditions are not leftovers, but latent potential within the landscape. By integrating ecology, culture, and design sensitivity, they can be leveraged to offer aesthetic delight, spatial meaning, and ecological resilience. Landscape architecture must shift focus toward these in-between realms to address contemporary challenges—from climate adaptation to social inclusivity—while grounding innovation in place-specific legacy.

This report contributes to bridging innovation, sustainability, and design by:

- Encouraging integrative, layered design thinking
- Demonstrating how transitions can support climate-responsive planning
- Providing a toolkit for creative but practical applications in urban and ecological contexts

By drawing from the philosophies of Olmsted, Wright, Appleton, and Shaheer, this study establishes that meaningful landscape design is found not just in destinations, but in the journey between them.

IMAGE CREDITS AND PERMISSIONS

FIGURE	TITLE	SOURCE/CREDITS	PERMISSION

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Figure 1	Prospect-refuge diagram	Adapted from Jay Appleton's theory via research publication	Fair use of Academic Purpose
Figure 2	Fallingwater	Western Pennsylvania Conservancy / Wikimedia Commons	Educational Use only
Figure 3	Sanskriti Kendra Complex Courtyard	Image courtesy: Archival references / Mohammed Shaheer Studio	Cited under fair use
Figure 4	Sunder Nursery	Aga Khan Development Network / Wikimedia Commons by Gryffindor, Pulkit Singh – Own works	Creative commons license
Figure 5	Central Park	NYC Parks Dept / public domain imagery	Public Domain
Figure 6	High Line NYC	Friends of the High Line / Wikimedia Commons	Creative Commons attribution
Figure 7	Capita Spring Urban Farm, Singapore	Courtesy: BIG – RSP Architects / Urban Redevelopment Authority (Singapore)	Educational with attribution
Figure 8	Pasona Urban Farm, Tokyo	Photo by Kono Designs / Toyo Ito	Used under academic fair use

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ISBN 978-93-342-4408-3

Wooden Craft Guilds as Heritage Systems across Cultures continuing along New Architectural Practices

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Abstract

This research investigates traditional wooden craft guilds as systems of heritage governance across four culturally diverse regions—Gujarat and Kerala in India, Kyoto in Japan, and Fez in Morocco. Historically, these guilds were not only economic institutions but also frameworks for regulating skills, ethical practices, spatial organization, and community identity. Through a comparative methodology, the study explores how guilds shaped both tangible and intangible heritage, such as built environments, rituals, and intergenerational knowledge transmission. The research identifies contemporary challenges—urban displacement, declining patronage, and loss of craft transmission—and draws lessons from successful models like Japan's recognition of master artisans and Morocco's craft-zoned souks. It proposes policy measures including craft zoning, artisan certification, community-led heritage boards, and integration of traditional crafts into urban planning. By reframing guilds as living institutions, the study advocates for conservation approaches that go beyond monument restoration to include the people, practices, and socio-spatial systems that sustain heritage.

Keywords: *Wooden Guilds, Heritage Governance, Traditional Crafts, Conservation Policy, Community Participation, Kapadvanj, Intangible Heritage.*

Introduction

Wooden craft traditions have historically shaped the cultural identity and built heritage of many towns across the world. In places like Gujarat and Kerala in India, Kyoto in Japan, and Fez in Morocco, these crafts were nurtured by traditional guilds—self-organized, community-based institutions that governed not only the production of goods but also the transmission of skills, cultural values, and social norms. These guilds functioned beyond economic collectives; they were systems of knowledge preservation, work regulation, and community cohesion.

Guilds played a vital role in sustaining both tangible elements like architectural forms and tools, and intangible ones such as rituals, ethics, and social hierarchies. They contributed significantly to heritage continuity, shaping the distinct identities of their respective regions. Despite modern shifts, traces of their governance models still influence craft practices and community organization.

This research explores the historical role of wooden craft guilds as systems of heritage governance and their potential to inform inclusive, sustainable conservation today. By studying guild traditions across four culturally diverse regions, it argues for a conservation approach that moves beyond preserving physical objects to also supporting the people, practices, and community frameworks that give them meaning and continuity.

Literature Review

Wooden craft guilds have historically played a pivotal role in shaping cultural identity, artisanal traditions, and urban form. Scholarly literature on this subject spans structural organization, socio-economic functions, and political relevance of guilds, with comparative insights from both India and global contexts.

In ancient and medieval India, artisan and merchant guilds, or *shreṇis*, functioned as influential socio-economic institutions. Misra (1963) details their governance mechanisms, including internal codes of ethics, apprenticeship systems, and regulatory frameworks. These guilds were instrumental in temple construction and, in some instances, even influenced urban planning. Ramaswamy (2004) emphasizes the

ISBN 978-93-342-4408-3

hereditary transmission of craft knowledge among communities such as the Vishwakarmas and Suthars, highlighting caste- or family-based frameworks that shaped skill preservation.

In Gujarat and Kerala, wooden craft traditions were embedded in the socio-religious fabric of daily life. The *Status Report on Traditional Craft Clusters* (Craft Revival Trust, 2011) underscores the role of crafts as economic foundations of historic towns, organized spatially into *vadas* (craft-specific neighborhoods) governed by internal systems of training and quality assurance.

Craft-based architecture—characterized by intricate brackets, door frames, and balconies—formed a visual and symbolic language of local identity. Thakur (2004) argues that such woodwork carried spiritual meaning and expressed community pride. This is further supported by INTACH (2004), which maintains that safeguarding traditional crafts requires a holistic approach—preserving not only architectural elements but also the people and practices behind them.

Colonial economic policies and industrialization led to the decline of these guild systems. Gupta (1998) critiques colonial favoritism toward industrial production, which marginalized artisanal economies and fractured local craft networks. In the postcolonial context, Hosagrahar (2005) observes that modern urban planning has displaced artisans from their traditional spaces, thereby severing critical links between craft, community, and place.

Menon (2009) advocates for a shift in conservation discourse—from material restoration to sustaining the living knowledge systems embedded within heritage practices. His concept of "living heritage" emphasizes continuity through practice and active community participation.

Globally, Japan provides a compelling example through its *miyadaiku* (temple carpenters), whose guild knowledge is protected by state policy. Nagata (2010) discusses the recognition of master artisans as “Living National Treasures” under Japan’s cultural property laws—an institutional mechanism that ensures transmission and respect for traditional skills.

UNESCO-ICHCAP (2017) reinforces this perspective by framing traditional craftsmanship as a vital component of intangible cultural heritage. According to UNESCO, safeguarding such systems is as crucial as preserving monuments and historic landscapes.

Collectively, the literature underscores that craft guilds are not merely professional collectives but are embedded institutions that shape skill transmission, social cohesion, and urban heritage. From Indian towns to Japanese temples, they have contributed significantly to how heritage is produced and preserved. However, modern shifts in planning, policy, and value systems continue to threaten these intricate networks. The literature thus strongly argues for a paradigm shift that integrates craft communities and their knowledge systems into contemporary heritage conservation frameworks.

Importance of Wooden Craft Guilds

Wooden craft guilds played a deeply embedded role in how traditional societies functioned—not just in the act of building or creating, but in how knowledge was managed, how work was organized, and how relationships were formed between artisans and the places they inhabited. These guilds were often shaped by long-standing traditions and unwritten rules, and their importance went far beyond craftsmanship alone.

Each guild operated as a structured unit where roles were clearly defined. Senior artisans, usually with decades of experience, were responsible for mentoring apprentices. This wasn't just a technical process but a social commitment—training often started in early childhood and continued for years under direct guidance. Because of this structure, knowledge wasn't just learned, it was absorbed through daily practice and repetition. This system helped maintain consistency and high standards across generations.

Skill transmission was at the core of guild systems. The knowledge of carving techniques, wood types, joinery methods, and tool handling was rarely written down. Instead, it was passed orally and physically,

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often kept within particular castes or family lines. Losing a guild often meant losing centuries of localized knowledge, because these practices were deeply tied to both the material and the environment in which they developed.

Guilds also served a strong social and cultural function. Many had links with local rituals, seasonal festivals, or temple practices. For example, tools were worshipped during annual festivals, and work was paused to observe communal customs. This ritualized structure gave dignity to the craft and allowed artisans to see their work as more than a livelihood—it was a cultural offering. These values gave guild members a shared identity that reinforced ethical behavior, community pride, and mutual respect.

Figure 1: Teaching craft skills to young generation

Figure 2: Craftsman performing Vishvakarma pooja

Economically, guilds helped stabilize artisan livelihoods. Members often received large orders from temples, merchants, or royal patrons as a collective, allowing work to be distributed among many. Guilds also provided support during periods of illness or old age, making them important not only for production but also for social welfare. Their ability to negotiate pricing or refuse unfair deals made artisans less vulnerable to exploitation.

Another critical role was the enforcement of ethics. Guilds maintained internal codes to ensure honesty in materials used, fairness in work division, and discipline in delivery timelines. Cheating or misrepresenting one's work could lead to penalties, loss of orders, or even expulsion from the guild—an outcome that had both financial and social consequences.

Guilds also influenced local governance. In many towns, leaders of artisan communities were consulted during urban planning or temple construction. Their knowledge of local materials, weather conditions, and sacred proportions made them valuable to decision-makers. Some even held advisory roles or were involved in dispute resolution within their town or community.

Figure 3: 1950s illustrated map of Fez, Morocco by a French artist, highlighting its historic medina, artisan zones, and cultural landmarks.

Figure 4: A lively view of Fez's souks, where artisans and traders preserve age-old craft traditions in the medina's bustling alleys.

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Visibly, one of the most lasting impacts of wooden guilds is found in built heritage. Intricately carved balconies, richly detailed doors, load-bearing wooden beams, and ornamented brackets still seen in older houses and temples are all testimonies to their expertise. These aren't just aesthetic features—they carry within them the knowledge of structure, climate response, and material behavior passed down over generations.

Over time, the role of guilds started to fade. Colonial industrial policies, changing land-use laws, and modern building materials weakened their networks. Young artisans started leaving traditional trades, and the tight-knit structure of guilds broke apart. But even today, fragments survive—in tools, in ritual practices, in family-run workshops—and they offer lessons on sustainability, knowledge sharing, and community-based governance, and advanced architectural skills.

Comparative Guild Systems Across Culture

The comparative study of guild systems in Gujarat, Kerala, Kyoto, and Fez presents distinct cultural responses to organizing and sustaining wooden craft traditions. Each region demonstrates structured mechanisms that govern transmission of skills, community identity, work ethics, and spatial integration within the town.

Gujarat's caste-based artisan settlements, Kerala's temple-bound carpentry, Kyoto's formal state-recognized guilds, and Fez's religiously framed craft zones illustrate region-specific modes of regulating craftsmanship. These systems influenced the urban landscape, patronage structures, and political roles of artisans.Yet the communities continue to grow with the influence of advanced architectural practices adopted in heritage structures.

Identifying Issues, Gaps, Patterns, and Lessons

The comparative analysis of traditional wooden craft guilds in Gujarat, Kerala, Kyoto, and Fez reveals a multifaceted system of heritage governance encompassing social, economic, and spatial dimensions. Despite the distinct cultural and historical contexts of each region, several recurring patterns, critical gaps, and instructive lessons emerge—offering valuable insights for contemporary community-centered conservation practices.

Common Patterns:

- Traditional craft guilds were deeply embedded in the socio-spatial fabric of towns, occupying defined urban zones such as vadas in India, souks in Morocco, and temple quarters in Japan.
- Skill transmission was primarily maintained through hereditary systems or structured apprenticeships, ensuring generational continuity.
- Rituals and cultural events—such as Vishwakarma Puja in India or tool veneration ceremonies in Kyoto—played a key role in reinforcing occupational pride and cultural cohesion.
- Guilds functioned as informal regulatory bodies, overseeing quality control, social conduct, and internal conflict resolution within the artisan community.

Identified Gaps and Challenges:

- In India, traditional guild systems have been marginalized within contemporary urban planning frameworks. Rezoning and redevelopment have led to the displacement of craft communities from their historical neighborhoods.
- There is an absence of institutional mechanisms for the formal recognition, certification, or financial support of master artisans—unlike Japan's state-supported system that designates craftspeople as "Living National Treasures."
- The younger generation is increasingly disengaged from traditional crafts due to economic insecurity, lack of institutional support, and the diminished social prestige of artisanal professions.
- Conservation efforts often emphasize architectural preservation while overlooking the intangible cultural systems—such as techniques, values, and community networks—that underpin these

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physical structures.

	Gujarat, India – Historic Wooden Architecture and Caste-Based Guilds	Kerala, India – Temple Carpenters and Ritualized Craft Transmission	Kyoto, Japan – Temple Guilds and National Heritage Policy	Fez, Morocco – Islamic Guilds and Craft Zoning
Guild Structure	Caste-based artisan communities like Suthars and Bhavsars organized informally in vadas; master artisans led local practice (Ramaswamy, 2004).	Hereditary guilds within the Vishwakarma community, transmission through strict apprenticeships tied to temples (Ramaswamy, 2004).	Formally structured guilds (Miyadaiku) with master-apprentice hierarchy, recognized under national heritage laws (Nagata, 2010).	Guilds organized by trade in specific market lanes; led by an amin and governed by Islamic principles of mutual responsibility (UNESCO-ICHCAP, 2017).
Skill Transmission	Oral tradition and hands-on training within family and caste, with rituals like Vishwakarma Puja reinforcing knowledge systems (Thakur, 2004).	Highly ritualized learning including fasting, prayers, and sacred geometry; knowledge passed through generations (Ramaswamy, 2004).	Apprenticeship under certified masters; state-supported programs protect and promote traditional skills (Nagata, 2010).	Skill transmission guided by guild ethics and monitored in workshops linked to religious routines (UNESCO-ICHCAP, 2017).
Socio-cultural Role	Wooden craftwork served as community identity markers; carvings on homes signified social and religious values (INTACH, 2004).	Temple carpentry was considered sacred work; guilds aligned with temple rituals and religious calendars (Thakur, 2004).	Carpentry viewed as a meditative and disciplined practice; tools and techniques carried symbolic meaning (Nagata, 2010).	Guild members observed collective fasting, prayer, and ethical codes; guilds promoted religious and moral integrity (UNESCO-ICHCAP, 2017).
Economic Function	Local patronage from merchant families; guilds negotiated commissions and ensured steady artisan employment (Craft Revival Trust, 2011).	Sustained by temple and royal support; community economy based around carpentry services for religious structures (Thakur, 2004).	Government-funded projects and temple contracts provided financial stability; status gave access to premium heritage jobs (Nagata, 2010).	Guilds managed pricing, resource distribution, and financial aid for members; souk zoning supported a stable artisan economy (UNESCO-ICHCAP, 2017).
Regulations and Ethics	Guilds enforced quality and moral standards; apprentices followed strict community norms (Ramaswamy, 2004).	Spiritual obligations guided work ethics; dishonoring guild rules led to exclusion from temple work (Thakur, 2004).	Master carpenters certified by the government follow codes of heritage conservation; rituals for tool use symbolize discipline (Nagata, 2010).	Islamic principles like futuwwa shaped honesty, discipline, and service; guilds regulated behavior and entry (UNESCO-ICHCAP, 2017).
Political Role	Some guild leaders acted as intermediaries in town planning and temple decisions (Ramaswamy, 2004).	Guilds worked closely with temple authorities and rulers, influencing architectural choices (Thakur, 2004).	Guild leaders advise government bodies and heritage councils; recognized legally in policymaking (Nagata, 2010).	Guilds coordinated with city officials to manage markets and influence urban trade regulations (UNESCO-ICHCAP, 2017).
Built Heritage Contribution	Guilds created ornate wooden elements—brackets, facades, balconies—that shaped the region's architectural identity (INTACH, 2004).	Temple roofs, beams, and sacred interiors were built by hereditary guilds using traditional techniques (Thakur, 2004).	Preservation of wooden temples with historic joinery reflects guilds' technical excellence (Nagata, 2010).	Woodwork and structural crafts in souks and madrasas reflect centuries of guild-regulated construction (UNESCO-ICHCAP, 2017).
Decline and Revival	Mechanization, zoning policies, and modern housing led to breakdown of traditional vada systems (Gupta, 1998).	Younger generations shifted away; ritual obligations now replaced by freelance work (Craft Revival Trust, 2011).	Still active due to state recognition, though fewer youth enter the trade; dependent on heritage funding (Nagata, 2010).	Revival efforts exist, but commercialization and tourist economy distort guild practices (UNESCO-ICHCAP, 2017).

Table 1: Comparative guild systems across cultures

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These findings underscore the necessity of reimagining heritage conservation not solely as the preservation of material artifacts, but as the active sustenance of living cultural systems. A more holistic and inclusive approach is required—one that centers on artisans as bearers of knowledge and stewards of heritage, thereby aligning cultural conservation with social equity and community empowerment.

Conclusion

This research has established that traditional wooden craft guilds functioned as intricate systems of heritage governance, deeply embedded in the social, economic, and spatial fabric of historic towns. The case studies from Gujarat, Kerala, Kyoto, and Fez demonstrate that guilds played a pivotal role not only in craft production but also in knowledge transmission, ethical regulation, spatial organization, and cultural continuity.

The decline of these systems—driven by centralized planning, industrialization, and socio-economic change—has disrupted the community-based models that once sustained both tangible and intangible heritage. While conservation efforts have largely focused on the preservation of structures, this study highlights the urgent need to expand the scope of heritage conservation to include the living practices, skills, and socio-cultural frameworks that give meaning to these built environments.

By reframing guilds as living institutions rather than static relics of the past, the research calls for conservation strategies that are participatory, inclusive, and rooted in the lived experiences of artisan communities. The study underscores the importance of policy measures such as formal recognition of master artisans, spatial protection for craft districts, and the revival of apprenticeship models. These initiatives not only support heritage preservation but also foster cultural resilience, economic dignity, and intergenerational continuity.

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ISBN 978-93-342-4408-3

RETHINKING COASTAL SETTLEMENT
A Comprehensive study: Towards Resilient and Regenerative Island Settlements through Integrated Systems

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Abstract

Coastal settlements face growing risks from sea-level rise, water scarcity, ecological decline, and weak infrastructure, challenges intensified in isolated communities like Marou Village, Fiji. This research rethinks coastal resilience by integrating energy, water, ecosystem, and socio-economic strategies to create self-sustaining, adaptive habitats. Few global models address these issues holistically for small islands. Through case studies - Rotterdam, Malé, El Hierro, Babcock Ranch, and Pentha, the study adapts best practices in water management, renewable energy, floating infrastructure, ecosystem restoration, and community-led design to Marou's unique context.

Keywords *- Coastal Resilience, Island Settlements, Water Management, Renewable Energy Systems, Ecosystem Restoration, Community-Led Design, Floating Infrastructure, Sustainable Tourism, Marou Village, Fiji.*

1. Introduction

Coastal settlements have long supported human civilization through trade, marine resources, and economic activity. However, their location makes them increasingly vulnerable to rising sea levels, stronger storms, water scarcity, and ecological degradation. These issues are especially critical in island communities, where limited resources and isolation intensify risks. Climate-related hazards such as cyclones, storm surges, and saline intrusion are compounded by unplanned urbanization and the loss of natural buffers like mangroves and coral reefs. As a result, infrastructure, livelihoods, and food security face growing threats. This research investigates integrated resilience strategies across six key areas: water management, renewable energy water management, renewable energy systems, ecosystem restoration, community- led adaptation, economic resilience, and architectural design. Using global case studies and comparative analysis, it identifies best practices and adapts them to the socio-cultural and geographical context of **Marou Village, Fiji**.

The paper is organized to review existing literature and strategies, evaluate gaps, and present a comprehensive design proposal tailored to Marou. The goal is to offer a replicable framework that supports regeneration and self-sufficiency in vulnerable island settlements.

1.1 Aim

To develop comprehensive strategies for coastal settlements, integrating adaptive architecture, to develop comprehensive strategies for coastal settlements, integrating adaptive architecture, and creating resilient, self-sustaining habitats.

1.2 Objectives

- Assess vulnerabilities in coastal settlements linked to water, energy, and environmental risks.
- Explore adaptive architectural strategies for sea-level rise and flooding.
- Identify sustainable water solutions like rainwater harvesting and desalination.
- Evaluate renewable energy potential (solar, wind, tidal) for self-sufficiency.
- Propose an integrated framework merging design, water, energy, and ecosystem resilience.

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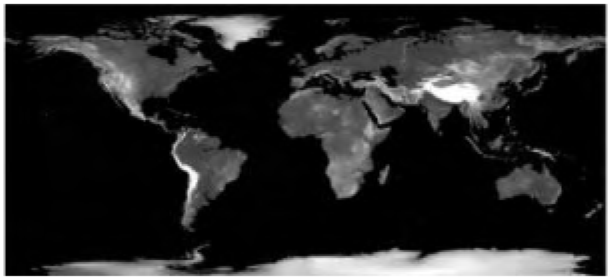


Fig.1 Elevation of the World

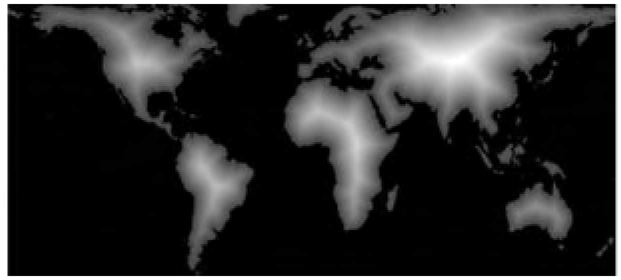
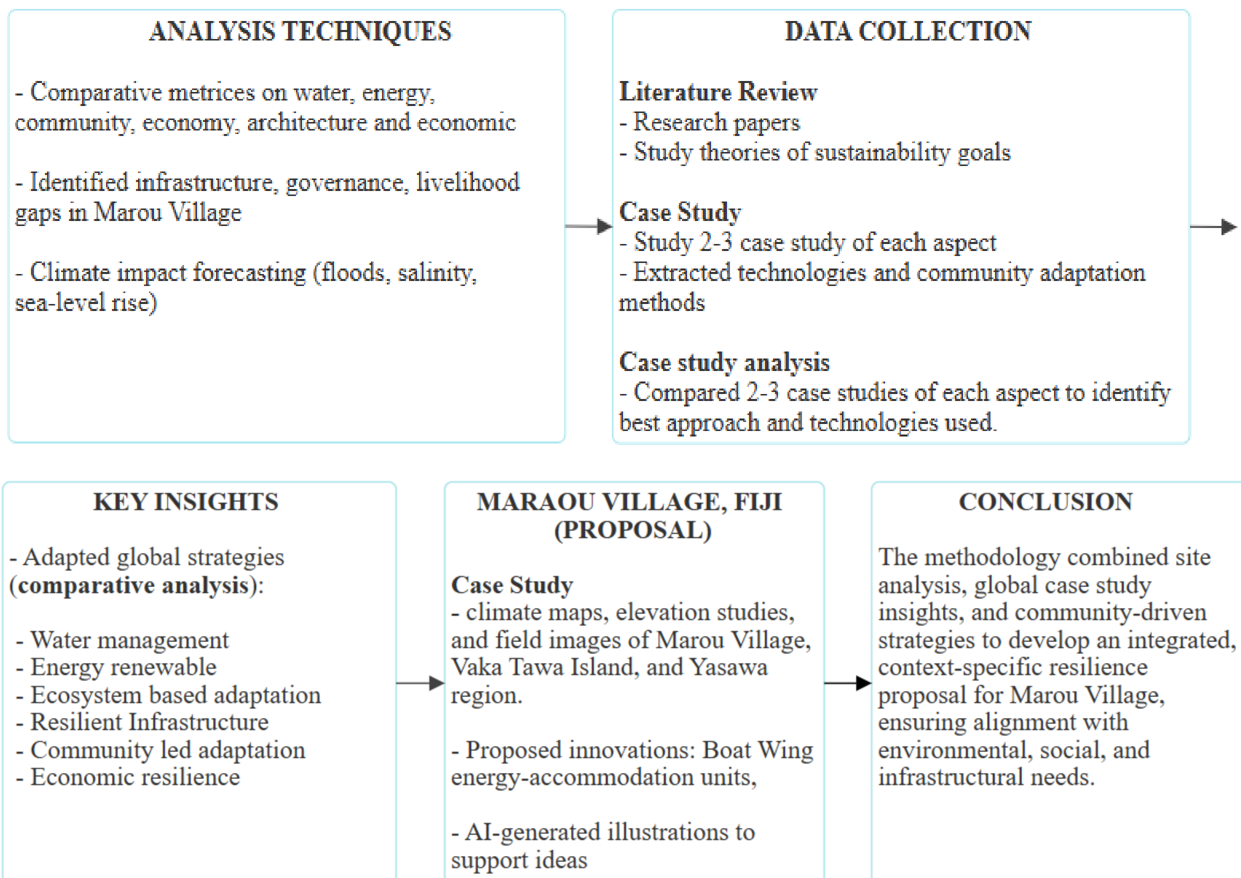


Fig. 2 Coastal proximity

A global analysis of human settlements in coastal zones highlights that, since a significant portion of habitable land lies at low elevations near the coast, even minor sea-level changes can lead to widespread displacement and severe infrastructural losses.

1.3 Methodology

This study adopts a qualitative, interpretive, and design-based methodology to examine resilience strategies in water, energy, ecosystem, architecture, and economic domains. It combines contextual analysis, case study evaluation, and proposal development, focusing on Marou Village, Fiji.



2. Framework and Literature review

Coastal settlements are human habitats located along shorelines, shaped by access to marine resources, fertile deltas, and trade routes. These areas support key economic activities like fishing, tourism, and

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shipping, but face increasing threats such as sea-level rise, erosion, and saline intrusion. Often situated near sensitive ecosystems like mangroves and coral reefs, they are ecologically important yet vulnerable. With rising urbanization and environmental stress, there's an urgent need for resilient, adaptive, and sustainable planning strategies.

2.1 Understanding coastal vulnerabilities

Coastal settlements face interconnected vulnerabilities across key sectors. Water scarcity is exacerbated by saline intrusion, insufficient rainwater harvesting, and poor stormwater management. Energy insecurity persists due to fossil fuel dependence and inadequate renewable infrastructure. Ecosystem degradation, particularly the loss of mangroves and coral reefs, weakens natural coastal defenses and threatens food security. Architectural shortcomings leave housing and infrastructure exposed to cyclones, flooding, and sea-level rise. Social vulnerabilities stem from weak governance, limited community participation, and heavy reliance on fragile marine resources. Economically, overdependence on tourism and fisheries, coupled with insufficient diversification, undermines long-term resilience and sustainability.

2.2 Aspect Theories

Recent coastal planning emphasizes a shift from rigid hard infrastructure, like seawalls and breakwaters, toward adaptive, ecosystem-based, and community-led strategies guided by models such as Integrated Coastal Zone Management (ICZM) and Nature-Based Solutions (NbS) (UN Habitat, 2018). Resilience theory, based on Holling's Adaptive Cycle (1973), explains how coastal systems, social, ecological, or infrastructural absorb shocks such as storms, floods, and resource depletion, progressing through phases of growth, conservation, release, and reorganization to sustainably recover. Ecosystem-Based Adaptation (EbA) integrates natural buffers like mangroves, wetlands, and coral reefs to reduce wave energy, prevent erosion, support biodiversity, and sustain livelihoods, as seen in projects across Sri Lanka, Vietnam, and Australia. Sustainable urbanism furthers resilience through climate-responsive design, circular water systems, and renewable energy integration; examples include Jakarta's raised infrastructure, Singapore's ABC Waters Program, and El Hierro's 100% wind-hydro energy model. The Socio-Ecological Systems (SES) approach blends community participation, traditional knowledge, and ecosystem restoration, demonstrated by India's Āśrayaṁ Project, Odisha's Pentha mangrove initiative, and the Shinnecock Nation's Indigenous adaptation plans, collectively promoting regenerative, self-sustaining coastal settlements.

3. Case Studies

3.1 Water Management (Flood adaptation, desalination, rainwater harvesting)

Rotterdam, Netherlands – Water-Sensitive Urbanism
Rotterdam integrates stormwater management, groundwater recharge, and flood-resilient infrastructure. Rainwater harvesting, water squares, and floating structures manage excess water, supported by smart levees and real-time flood monitoring.

Malé, Maldives – Floating Infrastructure & Desalination

Malé uses solar-powered desalination, rainwater harvesting, and floating homes to address freshwater scarcity and rising sea levels. Greywater recycling, floating wetlands, and automated flood barriers enhance resilience.

Jakarta, Indonesia – Flood Control & Stormwater Management

Jakarta combines rainwater harvesting, infiltration wells, bioswales, and a 32-km seawall to manage flooding and groundwater depletion. AI-controlled drainage, early warnings, and floating shelters further boost disaster preparedness.

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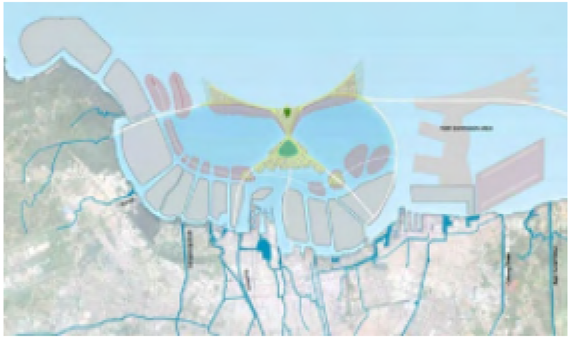

Fig. 3 The floods giant sea wall project in Jakarta, Indonesia

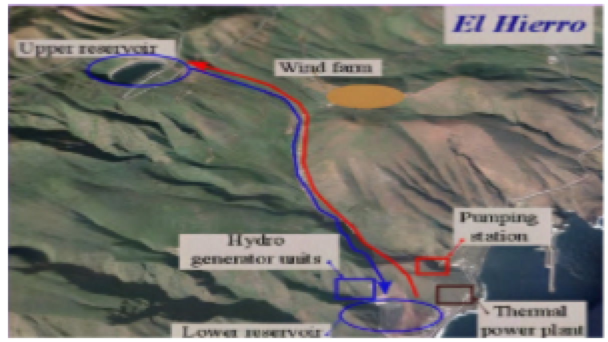

Fig. 4 Main elements of the hydro-wind power (Interconnection schematic Diagram)

3.2 Renewable Energy (Solar, wind, tidal, hybrid energy systems)

Babcock Ranch, USA – 100% Solar-Powered Town

Babcock Ranch operates entirely on renewable solar energy through a 75 MW photovoltaic array with battery storage and smart grids, ensuring reliable power. Solar energy also supports water treatment and efficient building design. The microgrid enables off-grid operations during disasters, demonstrating scalable, disaster-resilient energy solutions.

El Hierro, Spain – Hybrid Wind-Hydro System

El Hierro achieves near-complete energy independence by combining wind farms and pumped-storage hydroelectricity. Excess wind energy pumps water into elevated reservoirs, which is released to generate hydroelectric power when the wind is insufficient. The island integrates smart grids and wind-powered desalination, promoting resource security while reducing fossil fuel dependence.

Malé, Maldives – Floating Solar & Desalination

Malé addresses energy and water challenges through floating solar farms, rooftop panels, solar-powered desalination, and hybrid battery microgrids. Solar-assisted cooling and smart metering optimize consumption, though storm durability remains a challenge. This integrated model enhances energy resilience for island communities.

3.3 Ecosystem Based Adaptation (mangrove, coral reef, wetlands restoration)

Pentha, Odisha (India) – Mangrove Restoration

Pentha employs mangrove reforestation as a natural defense against erosion and storms. Community-driven planting of salt-tolerant species stabilizes shorelines, enhances fishery resources, and reduces soil erosion. This hybrid approach combines ecological restoration with coastal protection, ensuring long-term resilience.

Shinnecock Nation, USA – Wetland & Cultural Stewardship

The Shinnecock Nation integrates wetland restoration, native vegetation, and oyster reefs to reduce erosion and buffer floods. Traditional ecological knowledge guides sustainable adaptation, while living shorelines and carbon-capturing blue ecosystems enhance both biodiversity and climate resilience.

Malé, Maldives – Coral Reef Restoration & Marine Protection

Malé strengthens coastal resilience through coral transplantation, artificial reef structures, and marine protected areas (MPAs). Innovations like Bio rock technology promote coral regrowth, improving

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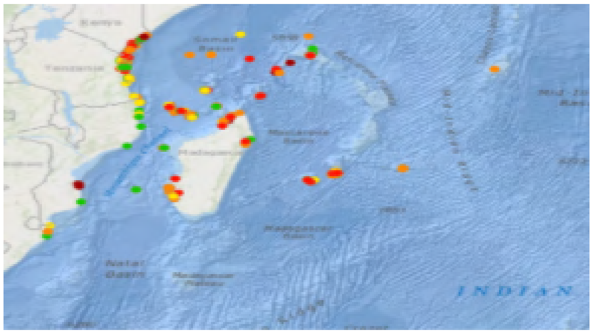
biodiversity and shoreline defense. Community stewardship and reef monitoring ensure sustainable restoration.



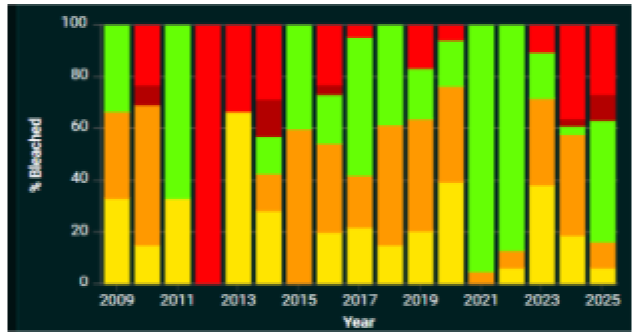


Fig. 5 WIO Coral reef bleaching observations Source - Indian ocean

Fig. 6 Regional % Bleaching observation Indian 2009-25

3.4 Resilient Infrastructure (cyclone-proof housing, floating settlements)

Rotterdam, Netherlands – Floating & Elevated Development

Rotterdam integrates elevated flood-resilient structures, floating neighborhoods like Schoonschip, and adaptive urban design to manage sea-level rise and storm surges. Multi-layered flood defenses, retention basins, and smart storm barriers strengthen long-term urban resilience.

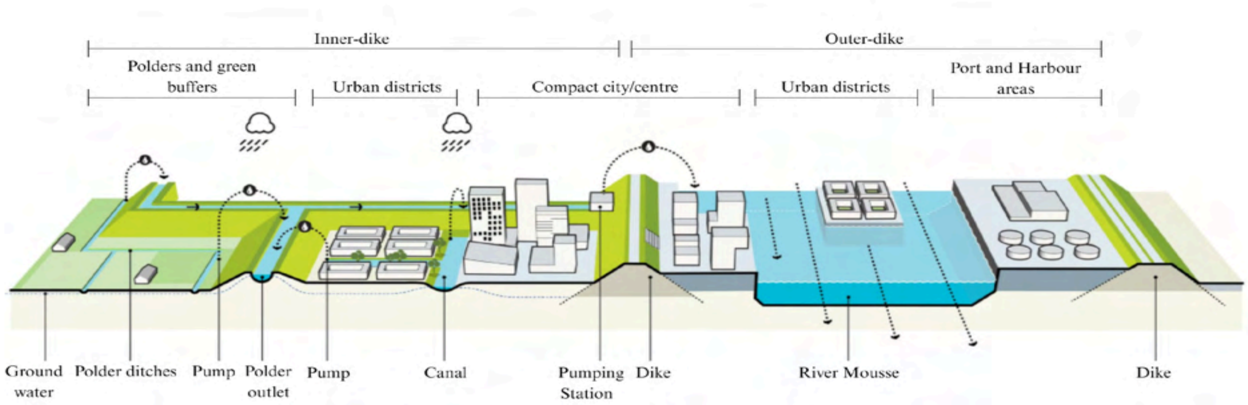


***Fig. 7* Adaptive strategies of Rotterdam**

Source - Urbanisten

Makoko, Nigeria – Floating Housing for Informal Communities

Makoko's floating homes, built from bamboo and recycled materials, provide adaptable, affordable solutions for flood-prone settlements. Innovations like the Makoko Floating School demonstrate modular, buoyant architecture suited to vulnerable coastal communities.

Jakarta, Indonesia – Giant Sea Wall & AI-Enabled Flood Protection

Jakarta employs a 32 km - long seawall, upgraded stormwater drainage, and AI-controlled networks to reduce urban flooding. Floating emergency shelters and strict groundwater regulations further safeguard the rapidly subsiding city.

3.5 Community led adaptation (traditional knowledge, participatory planning)

Ashrayam Project, India – Community-Driven Housing & Livelihoods

Ashrayam promotes cyclone-resistant homes using local materials and elevated plinths for vulnerable

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fishing villages. Integrated rainwater harvesting, floating fish farms, and participatory design empower communities to adapt sustainably.

Shinnecock Nation, USA – Indigenous-Led Resilience Planning

The Shinnecock Nation integrates traditional ecological knowledge with modern engineering. Wetland restoration, renewable energy microgrids, and elevated housing combine cultural heritage with environmental resilience.

Pentha, Odisha – Mangrove Restoration with Local Participation

Community-driven mangrove afforestation stabilizes shorelines, enhances fisheries, and protects against storm surges. Local stewardship ensures long-term success of this hybrid ecological and social resilience model.

3.6 Economic Resilience (sustainable tourism, blue economy, climate-adaptive businesses)

Costa Rica – Ecotourism & Nature-Based Livelihoods
Costa Rica exemplifies how sustainable tourism can drive economic growth while preserving ecosystems. Through strict regulations, protected areas, and eco-lodges, the country supports local employment, incentivizes conservation, and reinforces biodiversity protection.

Maldives – Blue Economy & Marine Resource Management

The Maldives integrates sustainable fisheries, marine conservation, eco-tourism, and renewable ocean energy into its economic framework. Initiatives like pole-and-line tuna fishing, coral reef restoration, and floating solar farms enhance marine health while ensuring stable livelihoods and reducing fossil fuel dependency.

Norway – Offshore Wind Development for Economic Transition

Norway leverages offshore wind to diversify its economy and reduce carbon emissions. Large-scale projects, such as Hywind Tampen, generate clean energy, create jobs, and support a workforce during transition from oil industries to renewables. Innovation grants and global technology exports bolster long-term economic stability.

Kumarakom, India – Backwater Tourism & Agritourism Integration

Kumarakom combines water-based tourism, agritourism, cultural activities, and eco-friendly accommodations to support local livelihoods. Initiatives like houseboat tourism, organic farming, and traditional performances generate income for farmers, fishermen, artisans, and hospitality workers.

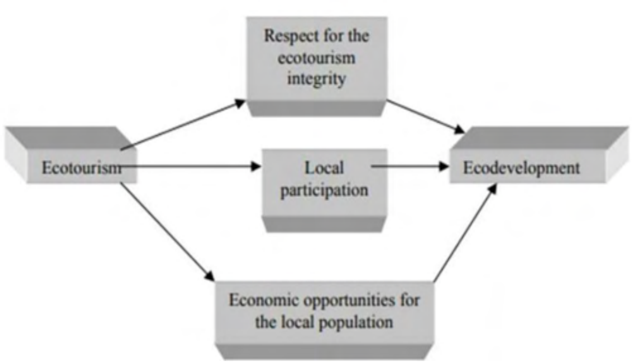

Fig. 8 Elements involved in the development of ecotourism Source - www.frontiersin.org

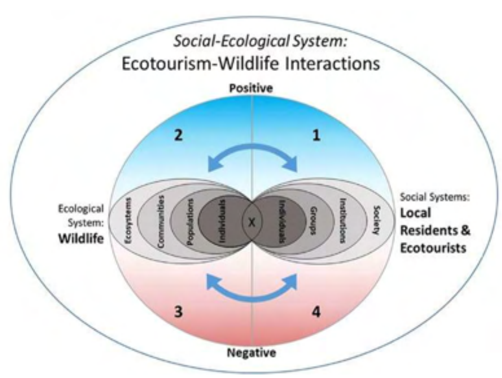

Fig. 9 A social-ecological systems framework for ecotourism-wildlife interactions Source - researchgate.net

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4. Comparative Analysis of Case Studies

4.1 Water Management

Aspect	Rotterdam (Netherlands)	Malé (Maldives)	Jakarta (Indonesia)
Rainwater Harvesting	Green roofs, water squares	Rooftop tanks, floating settlements	Household & community tanks
Desalination	Not required (freshwater from delta)	Solar-powered desalination systems	Not applicable
Flood Protection	Smart levees, bioswales, retention ponds	Floating structures, seawalls	Giant sea wall, AI-driven drainage
Groundwater Recharge	Infiltration wells, controlled replenishment	Not prioritized (saline groundwater)	Retention basins, regulations on use

Key findings - Water management strategies include rooftop rainwater harvesting with first-flush diverters, solar-powered desalination, and decentralized floating treatment units for reliable water access. Permeable pavements, infiltration wells, bioswales, and retention ponds enhance groundwater recharge and reduce surface runoff. Groundwater regulations prevent over-extraction and salinization, while seawalls, artificial reefs, and AI-based early warning systems offer natural and technological flood protection.

4.2 Renewable Energy

Aspect	Babcock Ranch (USA)	El Hierro (Spain)	Malé (Maldives)
Primary Energy Source	100% solar with battery storage	Hybrid wind-hydro system	Floating solar, hybrid solar systems
Energy Resilience	Self-sustaining microgrids	Pumped storage hydro for stability	Solar-powered desalination, smart grid
Innovations	Solar-powered utilities, smart grid	Wind-driven desalination, smart grids	Floating solar farms, real-time monitoring

Key findings - Wind farms, and hybrid wind-hydro systems to maximize renewable generation and ensure reliability. Solar-powered desalination reduces fossil fuel dependency for freshwater needs. Self-sustaining microgrids with battery storage, reinforced storm-resilient energy infrastructure, and AI-integrated smart grids enhance energy security. Passive cooling, solar-assisted systems, and energy-efficient buildings further reduce consumption, while decentralized solar, wind, and hydro solutions promote local self-sufficiency.

4.3 Ecosystem-Based Adaptation

Aspect	Pentha (Odisha, India)	Shinnecock Nation (USA)	Malé (Maldives)

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Coastal Protection	Mangrove reforestation with seawalls	Wetland restoration, oyster reefs	Coral transplantation, artificial reefs
Community Involvement	Local participation in restoration	Indigenous-led management	Community coral nurseries
Innovation	Blue carbon, hybrid defense models	Blue carbon projects, cultural integration	Bio rock reefs, genetically resilient corals

Key findings - Ecosystem-based adaptation combines mangrove reforestation with seawalls for storm protection, traditional wetland restoration for flood control, and coral transplantation with artificial reefs to enhance biodiversity and coastal resilience. Blue carbon initiatives support climate mitigation through wetland conservation, while AI and drone-based reef monitoring improve long-term restoration efficiency. Community-led afforestation strengthens mangrove sustainability, and genetically resilient coral strains help address bleaching risks, ensuring durable ecological protection.

4.4 Resilient Infrastructure

Aspect	Rotterdam (Netherlands)	Makoko (Nigeria)	Jakarta (Indonesia)
Adaptive Infrastructure	Elevated & floating structures	Floating housing, amphibious models	Giant seawall, flood-adaptive shelters
Flood Management	Storm surge barriers, water plazas	Buoyant structures, raised walkways	AI-controlled drainage, early warnings
Materials/Tech	Flood-resilient design, modularity	Locally sourced floating foundations	Disaster-proof infrastructure, sensors

Key findings - Resilient infrastructure integrates elevated housing, floating roads, and amphibious buildings to cope with sea-level rise and flooding. Floodable parks, permeable pavements, and adaptive waterfronts manage excess water, while disaster-resistant materials like salt-resistant concrete, bioengineered reefs, and modular designs enhance durability. Smart monitoring systems with IoT sensors and AI-driven early warnings enable proactive disaster response. Off-grid renewable energy, rainwater harvesting, and water recycling ensure resource self-sufficiency, while community-led planning and indigenous knowledge promote inclusive, long-term resilience.

4.5 Community-Led Adaptation

Aspect	Ashrayam (India)	Shinnecock Nation (USA)	Malé (Maldives)
Community Role	Participatory planning, resilient housing	Indigenous knowledge in planning	Community-led coral restoration
Resilience Strategies	Local materials, salt-resistant crops	Renewable microgrids, cultural stewardship	Floating homes, solar desalination
Livelihood Integration	Livelihoods like fish farms	Heritage preservation, eco-resilience	Marine-based economy, eco-tourism

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Key findings - Community-led adaptation emphasizes participatory planning, indigenous knowledge, and ecological stewardship to build resilience. In Ashrayam, India, communities engage in planning and adopt resilient housing with local materials and salt-resistant crops to safeguard livelihoods like fish farming. The Shinnecock Nation integrates traditional knowledge, renewable microgrids, and cultural preservation to enhance eco-resilience. In Malé, Maldives, communities lead coral restoration efforts, supported by floating homes, solar desalination, and marine-based economies like eco-tourism for sustainable livelihoods.

4.6 Economic Resilience

Aspect	Costa Rica (US)	Malé (Maldives)	Norway
Key Economic Drivers	Ecotourism, protected biodiversity	Blue economy, sustainable fisheries	Offshore wind, renewable exports
Nature-Based Integration	Eco-lodges, carbon sequestration	Coral restoration, marine protection	Ocean energy, green jobs
Sustainability Outcomes	Conservation-linked income growth	Reduced fossil fuel dependency	Workforce transition, energy security

Key findings - Sustainable coastal economies emphasize ecotourism, marine conservation, and indigenous cultural tourism to boost local income. Blue economy initiatives promote sustainable fisheries, offshore renewables, and ocean-based industries for long-term stability. Renewable energy integration like offshore wind, tidal, and solar reduces costs and creates green jobs. Regulated fishing, marine protected areas, and eco-friendly aquaculture prevent resource depletion. Resilient infrastructure such as floating settlements and cyclone-proof facilities safeguard investments, while floating economic hubs like treehouses and eco-resorts support tourism. Nature-based protections using mangroves, coral reefs, and wetlands preserve ecosystems, reinforced by policy incentives and green investments.

5. Comprehensive sustainable development proposal for Marou village, Fiji

5.1 Introduction

Marou Village, located on Lagi Island, Fiji, is a small coastal settlement comprising approximately 370 households. Like many Pacific Island communities, it faces acute climate vulnerabilities, including rising sea levels, frequent cyclones, freshwater scarcity, energy insecurity, and ecosystem degradation. The community relies heavily on fishing, small-scale tourism, and natural resources, with limited infrastructure and accessibility, heightening its exposure to climate risks.

5.2 Case study

Marou's remote location and low-lying coastal geography make it highly susceptible to coastal erosion, flooding, and storm surges. The nearby Yasawa School, located in the hilly interior, reflects the area's dispersed social infrastructure, while Vaka Tawa Island holds potential for expanding tourism activities. Surrounding coral reefs and mangrove belts provide critical natural protection but remain ecologically fragile. **Key challenges** identified include - Freshwater scarcity due to limited rainwater harvesting and no large-scale desalination, Inadequate energy infrastructure reliant on fossil fuels, Coastal erosion, land loss, and habitat degradation, Economic vulnerability with overdependence on fishing and informal tourism, Limited resources for large-scale adaptation measures due to small population size and cultural land tenure systems. This site-specific understanding highlights the urgent need for integrated, low-impact, and community-driven resilience strategies tailored to Marou's environmental and socio-economic realities.

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Fig.10 Yasawa School

Fig.11 Marou Village House

Fig. 12 Existing reservoir

5.3 Transition from strategies to site specific innovations

The design development for Marou Village transitions from broad climate strategies to grounded, site-responsive solutions that directly address the settlement's vulnerabilities. Housing, infrastructure, and utilities are adapted to withstand flooding, sea-level rise, and resource scarcity through elevated structures, floating systems, and decentralized energy and water networks.

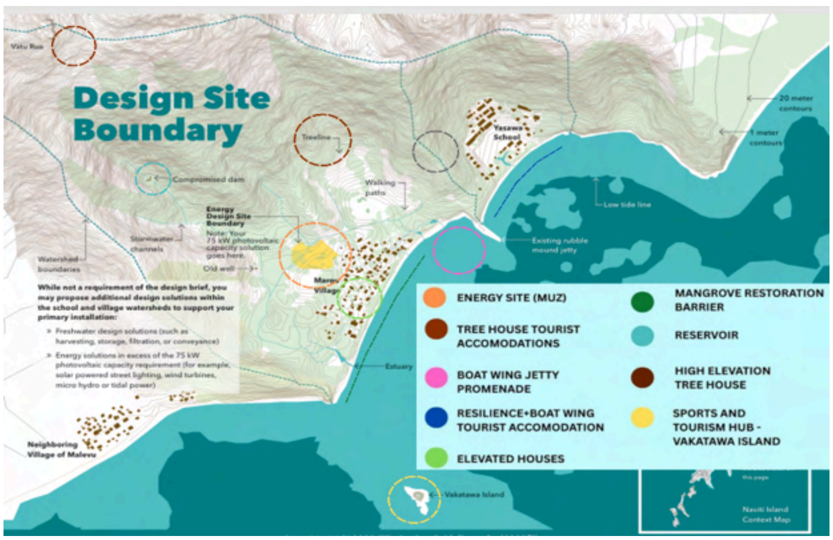

Fig. 13 Master Plan of Marou Village, Naviti Island, Fiji

Fig. 14 Zoning

Technological interventions are integrated with sensitivity to local lifestyles, ensuring that materials, construction methods, and systems align with the community's social and environmental context. The result is an adaptive, resilient settlement that enhances safety, self-sufficiency, and long-term sustainability.

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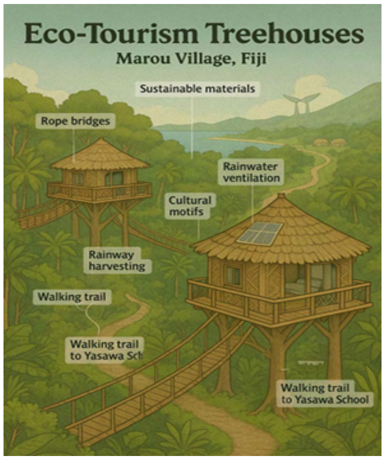
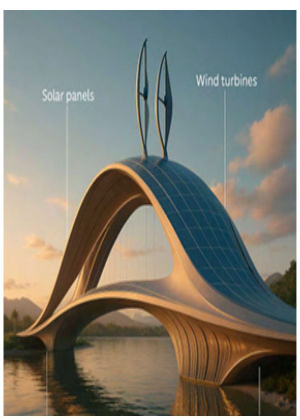
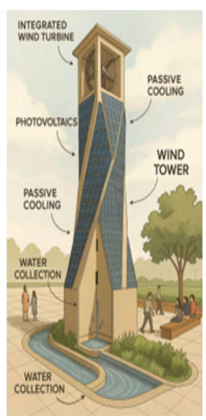
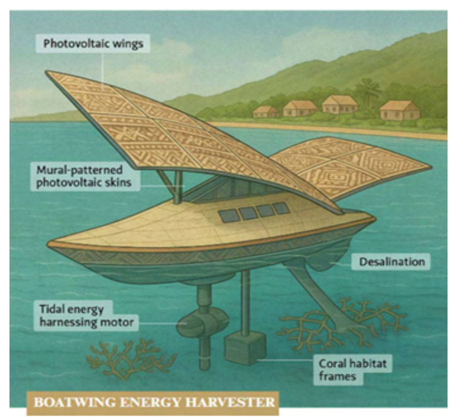


Treehouse Accommodations (Hilly Zone) and Vaka Tawa Island Elevated eco-cabins near Yasawa School and Marou, built with local materials for minimal impact. Supports nature-based tourism and local livelihoods.	**Resilience Shelter & Governance Node** Elevated emergency hub with power backup, satellite communication, and resource stockpiles; doubles as a community training and meeting space.	**Vaka Tawa Island – Watersports & Activities Hub** Recreation zone connected to Marou with watersports, Boat Wing units, and treehouse stays. Diversifies tourism, boosts the economy, and decentralizes activity pressure.







Energy Spine with Multi-Functional Overhead Element Elevated walkway integrated with wind catchers, solar panels, dehumidifiers, and lighting; provides energy, water, and shaded pedestrian access through vulnerable zones.	**Boat Wing Energy Harvester** Hybrid solar, wave, and tidal generator with photovoltaic wings and ecosystem modules, supplying off-grid clean energy for community and water systems.

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Dual Rain Gardens with edible landscaping manage rainwater, purify greywater, and produce food.	**Boat Wing Accommodation Units (10 Units)** Modular, mobile housing with solar power, desalination, rainwater harvesting, and floatation, offering disaster-resilient, self-sustaining tourism and community benefits.

6. Conclusion

This research highlights the urgent need for integrated, adaptive strategies to build resilience in vulnerable coastal settlements facing rising sea levels, resource scarcity, and ecosystem degradation. Sustainable water management through rainwater harvesting, desalination, and recycling is critical to securing long-term freshwater access. Equally, decentralized renewable energy systems, combining solar, wind, and tidal power, are essential for energy self-sufficiency. The restoration of mangroves, coral reefs, and wetlands strengthens natural coastal defenses while preserving biodiversity and livelihoods. Climate-adaptive infrastructure including elevated structures, flexible architecture, and resilient materials ensures habitability despite increasing environmental risks. Crucially, community-led adaptation, grounded in local knowledge and inclusive decision-making, fosters ownership and culturally appropriate solutions. Economic resilience depends on diversifying livelihoods, integrating sustainable tourism, and promoting green industries to reduce dependence on vulnerable sectors. Ultimately, transforming coastal settlements into regenerative, self-sustaining communities demands a shift from reactive responses to proactive, system-based planning where technology, ecology, and community empowerment converge to create long-term resilience.

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ISBN 978-93-342-4408-3

SMART AND SUSTAINABLE PAPER WASTE MANAGEMENT THROUGH S.T.I. IN ACADEMIC INSTITUTIONS

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Abstract

The growing environmental burden of paper waste in academic institutions demands urgent and innovative solutions. Despite increased digitalization, paper remains widely used across campuses in India. Integrating Science, Technology, and Innovation (STI) within the framework of national missions such as Atma Nirbhar Bharat and Swachh Bharat Abhiyan offers a transformative approach to waste management. This paper proposes a sustainable model for paper waste handling using the 3R principle- Refuse, Reuse, Recycle alongside smart technologies like sensor-based bins, reuse labs, and student-led innovation hubs. The phased strategy includes audits, infrastructure development, and partnerships with municipal bodies. Institutionalizing waste minimization through entrepreneurship training and reuse practices can foster a culture of circular economy, sustainability, and socio-technological growth [3]. Such a framework not only manages paper waste efficiently but also aligns with India's broader developmental vision under the Viksit Bharat initiative.

Keywords: *Paper Waste, STI, Circular Economy, 3Rs, Swachh Bharat, Atma Nirbhar Bharat, Academic Institutions*

1. INTRODUCTION

India's vision of becoming a developed nation as envisioned under Viksit Bharat requires a robust integration of Science Technology and Innovation (STI) across all sectors, including waste management. Despite the growing trend of digitization with rising concerns around environmental degradation, paper waste remains a persistent issue in Indian educational institutions. Although digital tools have reduced the dependency on printed documents, the demand for physical paper persists for administrative, academic, and creative purposes. This calls for a robust and future-ready strategy rooted in science, technology, and innovation (STI).National programs like Atma Nirbhar Bharat and the Swachh Bharat Mission emphasize local resilience and responsible practices of behavioral transformation, innovation and local empowerment in achieving sustainable development [2]. In response to the continued use of paper in academic campuses, as centers of learning and experimentation, are ideal environments for implementing sustainable waste management solutions. This paper presents a structured and replicable approach for paper waste management with minimum environmental impact.

2. BACKGROUND AND NEED

India generates over 8.9 million tons of paper annually [1], a significant portion of which is consumed by academic institutions. While efforts toward digitization are ongoing, infrastructural gaps and behavioral patterns have kept the reliance on paper intact.

Traditional methods of waste disposal have proven insufficient to handle the volume and type of waste being generated. Without proper segregation, most recyclable paper ends up in landfills or is incinerated, contributing to pollution and carbon emissions. It is in this context that STI can bring about a paradigm shift in waste lifecycle management.

3. OBJECTIVES

1. To assess current trends and practices of paper waste usage in academic institutions.
2. To explore STI-enabled solutions for effective paper waste management.

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3. To propose a structured implementation model based on audits, infrastructure, and partnerships.
4. To integrate sustainability education and green entrepreneurship into campus ecosystems.
5. To recommend collaboration between institutions and municipal authorities.

4. METHODOLOGY

This study is based on a mixed-methods approach that includes:

- Review of secondary literature including government reports, policy documents, and case studies.
- Observational data from academic campuses practicing waste management.
- Mapping of national initiatives such as Atal Innovation Mission and Project Dhruv.
- Interviews with institutional administrators and sustainability officers.

5. DATA ANALYSIS

Project Dhruv: Demonstrated potential in skill development and circular practices.

IITs/NITs Waste Recycling Models: Many institutions have initiated internal waste audit mechanisms and have installed shredding + recycling units [4],

These models can be replicated in other institutions with localized customization.

Most campuses show a consistent decline in paper waste, Indicating improved awareness and adaptation of digital/STI based practices.

Following are some list of the institution:

Campus	Institution	Year 2022 (Kg)	Year 2023 (Kg)	Year 2024 (Kg)
A	Indian Institute of Technology, Delhi (IIT Delhi)	1800	1600	1300
B	University of Delhi (North Campus)	2200	2000	1700
C	Guru Gobind Singh Indraprastha University, Dwarka	2100	1900	1600
D	Jamia Millia Islamia, New Delhi	1750	1600	1400
E	Amity University, Noida	1500	1350	1100

Table 1. Paper Waste Generation Trend (in Kg) by Institute

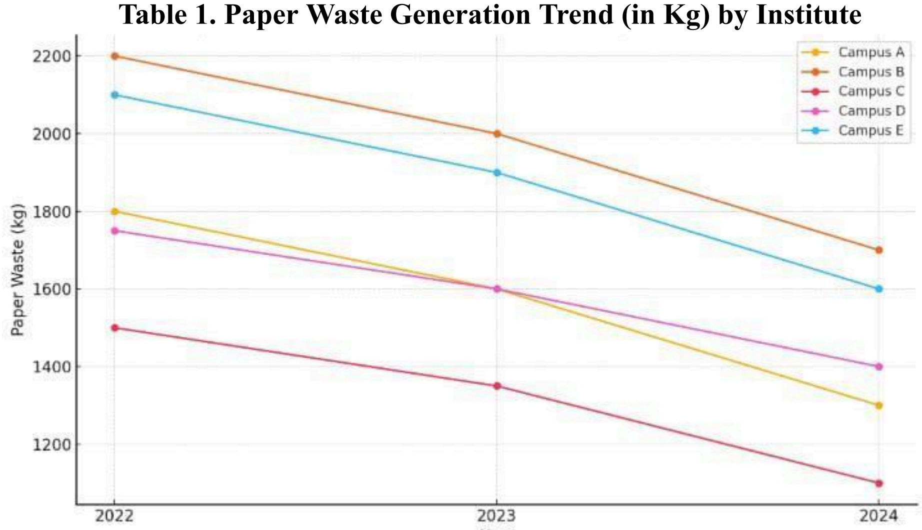

Figure 1. Paper Waste Generation in Academic Campuses (2022-2024)

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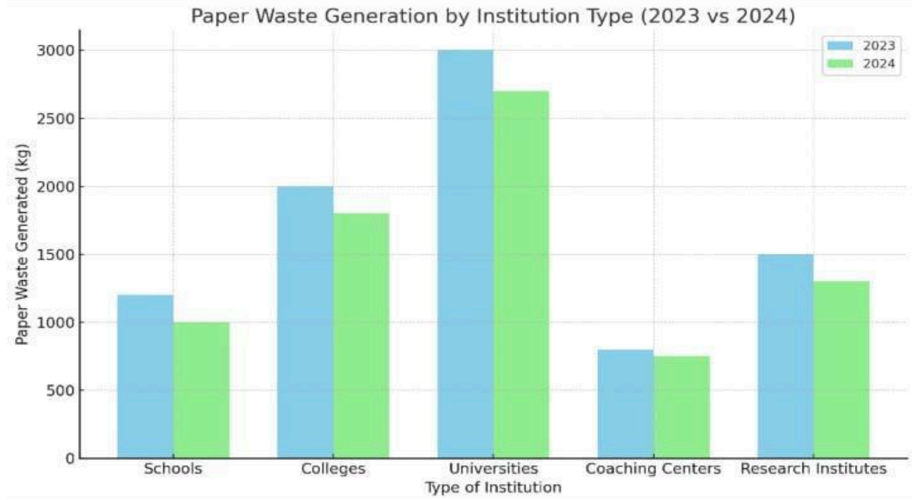

Figure 2. Paper Waste Generation by Institution Types (2022-2024)

6. PROPOSED STI-BASED MANAGEMENT FRAMEWORK

6.1 PHASE I: WASTE AUDIT AND AWARENESS

Conducting baseline audits of paper consumption and disposal patterns is the foundation of effective management. Educational campaigns involving students and faculty can drive behavior change. Digital alternatives like e-books, online submission portals, and shared drives can replace printed materials.

6.2 PHASE II: INFRASTRUCTURE DEVELOPMENT

Installation of sensor-based smart bins that enable real-time monitoring of waste segregation can enhance accountability. Reuse labs for converting paper waste into usable goods (seed paper, recycled notebooks, art material) can be integrated into design or craft studios. Collaboration with local startups can bring in technical expertise.

6.3 PHASE III: MONITORING AND INSTITUTIONAL PARTNERSHIPS

Regular monitoring through dashboards and feedback systems ensures that the system is responsive and adaptive. Formal collaborations through MoUs with municipal corporations and NGOs can facilitate streamlined recycling, skill development, and community participation.

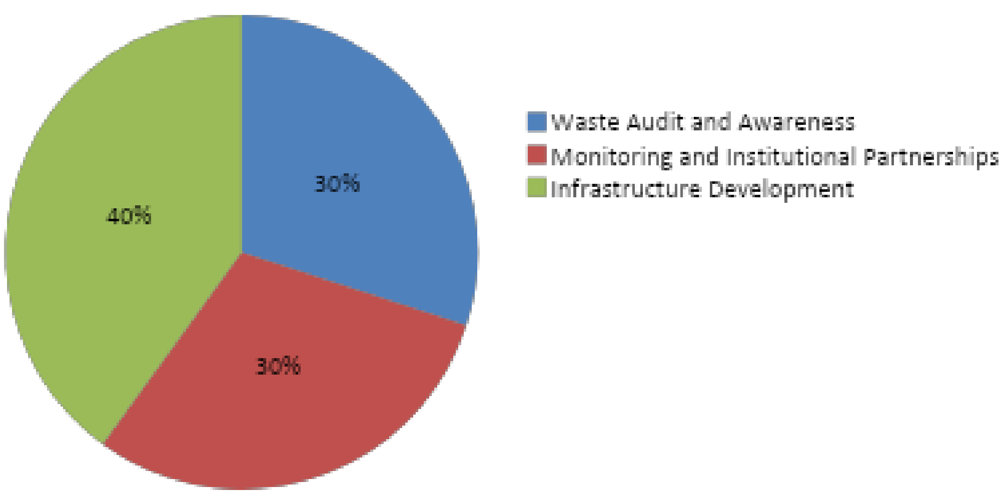

Figure 3. Phase-wise Implementation Model

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7. ROLE OF NATIONAL MISSIONS

Government programs such as the Atal Innovation Mission and Swachh Bharat Mission offer a policy foundation for institutional sustainability practices. Atal Tinkering Labs encourages innovation among students, while the One Nation program under Atma Nirbhar Bharat supports localized, self-reliant models.

These frameworks foster a culture of experimentation, hands-on learning, and awareness that is essential for long-term sustainability.

8. EXPECTED OUTCOMES

- Reduction in volume of paper waste by 30–50% over a year.
- Increased student engagement through project-based learning on sustainability.
- Revenue generation through the sale of upcycled paper products.
- Development of green entrepreneurship and waste literacy across campus.

9. CHALLENGES AND RECOMMENDATIONS

Challenges:

a. Resistance to digital adoption among faculty
b. Initial funding requirements for infrastructure
c. Lack of skilled personnel for reuse labs

Recommendations:

a. Integrate waste literacy into orientation programs
b. Leverage CSR funding from industries
c. Establish campus-wide sustainability clubs

10. CONCLUSION

Smart and sustainable paper waste management in academic institutions is not merely an environmental concern but a platform for experiential learning and innovation. STI offers tools and systems that, when supported by institutional and governmental collaboration, can help shift India towards a circular and sustainable economy. Implementing this model across campuses will contribute significantly to national goals under the Viksit Bharat initiative.

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ISBN 978-93-342-4408-3

ENHANCING DISTRICT CENTRE : Identifying Problems and Implementing Solutions

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Abstract

As population is accelerating day by day which leads to accelerated development in the society and this causes maximum land use. District centres are designed to divert the population from the central business district and it is built on large areas due to which some areas are not maintained properly. So, the Architect has to play the crucial role to make any place welcoming and user-friendly. In this paper, it is discussed how to enhance the quality of life in the district centre by enhancing vehicular and pedestrian movement, streetscape and landscape, more and more incorporation of public interactive spaces and also how to cater dead zones.

INTRODUCTION

Today's population is growing, and development is also accelerating, so it leads to maximum impact on land. District centres are built on large areas, and some parts of them are not properly maintained, so malls are taking the place of district centres. Malls provide quality of life such as interactive spaces, streetscapes, and landscapes, whereas in district centres, the quality of life is limited to commercial or service hubs. So that is why people like to go to malls. There is a need to maintain a sense of life in district centres that can help handle dead zones, streetscape, landscape, and vehicular and pedestrian movement, so the purpose of this paper is to improve district centres by identifying problems and implementing the concerned solutions.

Need of the research: This study is required because, in order to revitalize district centres and improve their aesthetics and quality of life, research on dead zones, landscaping, streetscape, and pedestrian and vehicular mobility is crucial.

Aim: To identify the problems faced in district center design and implementing its solutions.

Objectives:

- To study about the district center and its importance.
- To study about function, design and public interactive spaces of district center.
- To analyze the streetscape and landscape of the district center.
- To identify dead zones.
- To identify problems and recommending its solution to enhance the district centres design for achieving better performance

Scope:

- Spotting out such zones and enhancing the free flow circulation to make the district centre more functional.
- To improve traffic and pedestrian circulation to reduce congestion and make the district centre more functional.

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Limitations:

- This research has been limited to Delhi.
- Only streetscape, landscape, pedestrian and vehicular movement and dead zones have been covered in this research.
- Building design of the district centre has not been covered.
- Services of the district center have not been covered.

Research Questions:

Q1. What is a district centre and its importance?

Q2. How function, design and public interactive spaces of district centers play an important role?

Q3. How many district centres are in Delhi?

Q4. How streetscape and landscape can create a sense of life?

Q5. How are district centers and central business districts different?

Methodology:

- Literature Study: Understanding district centre, public interactive spaces, streetscape and landscape, dead zones.
- Case Studies: Data collection from district centres (NSP, Bhikaji Cama, Nehru Place, Rajendra Place, Saket).
- Comparison and Analysis: Identifying common issues and challenges.
- Recommendations and conclusion: Suggesting design solutions based on problems identified.

LITERATURE STUDY

A District Centre is the hub for multi-nodal activities in different parts of the city. It is designed by the government in different parts of the city to cater the needs of the different particular zones and its neighborhood community. It serves non-residential uses like commercial hub, public and semi-public, utilities, service and repair and it also are the centers for socio-cultural activity where the people can get together and interact with each other. It aims to give the community, quality of life.

Features in District Centre

1. **Landscape:** It is Influential element in a design. It enhances the aesthetic appeal and provides users with opportunities for *relaxation and outdoor activities*. *It connects the user to nature*.
2. **Interaction Spaces:** It plays a major role for interaction in the District Centre. It can help to break continuity and leads to visual separation of the buildings. They encourage people to relax and socialize with each other.
3. **Streetscape:** It plays an important role in designing any street. They are used in daily lives. Streetscape can transform grey spaces into green, vibrant, and pedestrian friendly.

Need of district centre

District Centre helps to control economic activity so that it can reduce congestion in CBD. It accommodates amenities and services for the neighborhood community and zone which it is in. It supports the local economy by providing opportunities for small businesses and industries. It often serves as hubs for community activities, social interaction and community development. It caters the commercial needs of different zones of the city

How District Centres are different from Central Business District: District centres are accessible from major transport nodes and are surrounded by residential areas with pedestrian-friendly approaches. They are smaller in scale than CBDs and typically serve around 5,00,000 people, whereas CBDs are the economic heart of the city and serve a wider region.

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Figure 1 Illustration showing need of district centre. (Source: PNG.com)

Key elements of district centres include:

1. **Vehicular and pedestrian movement:**

It is a primary element of the district centre. It functions as the circulatory system of the district centres. If vehicular and pedestrian movements are not designed properly it leads to congestion and disturb the whole movement and workability

Measures taken while designing vehicular and pedestrian movement

- **Safety and comfort**: Streets should be designed with wide sidewalks, pedestrian crossings, and ample lighting to ensure safety and comfort for pedestrian's planters to reduce congestion between pedestrians and vehicular movement.
- **Ecology:** Planting trees along streets can lead to reduction of heat island effect, mitigate air pollution, and provide shade and comfort to the pedestrians. Trees can also be used to segregate pedestrians from roads as well as buildings.
- **Easy accessibility:** Sidewalks should be widened enough and free of obstacles so that it could be easily accessible for pedestrians.

2. **Public interactive spaces:**

Public interactive spaces are the focal point in any area. It is the focus for community engagement, leisure activities, cultural events and social interaction. Nowadays public interactive spaces in District Centre have lost their value and their uniqueness due to lack of sitting, gathering points etc. Public interactive spaces provide gathering spaces for all ages, by encouraging the sense of belonging.

- **Access and Linkages:** Public spaces should have easy ways to get in and get through, it can be achieved by visual and physical connections. The surrounding of public places should avoid any visual barrier.
- **Comfort and Image:** Creating public spaces is easy but people's perception, behaviors, and their overall experience is important while designing the public spaces.
- **User and activities:** A Public Place is user- centered design which will cater the needs and preferences of users which will lead to inclusive and welcoming environments for them. Activities in public places give it a unique sense that makes the place special.
- **Sociability:** It is an aspect that can be difficult to attain but it can be attained through thoughtful design and planning. This factor can help to create a vibrant and inclusive environment where people feel welcome and connected.

3. **Streetscape and Landscape:**

Streetscape and landscape are the important aspect of any design. It helps to create visual connection or can also help to break the visual continuity in any design. Streetscape and landscape in a district Centre involve various factors to create an attractive, functional, pedestrian friendly environment and user centered design.

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Elements of streetscape and landscape

- **Sidewalks:** Sidewalks are the essential element of the streetscape; it is provided for pedestrians to move safely and comfortably away from roads. Sidewalks should be designed widely so that they do not create congestion.
- **Plantings Strip**: It helps to create a buffer between roads and sidewalks. Planting trees on the sidewalks can reduce heat island effect and can provide shade to the user for their comfort.
- **Lighting:** Lighting design is needed for the comfort of users, providing them security and ambiance. It could help in creating visual interest of the users.
- **Way-finding and signage:** Clear signage and maps can help pedestrians to navigate the District Centre easily. Elements can also be incorporated on the street for easy navigation for the user.

4. **Dead zones:**

Dead zones are the spaces which lack activity or functionality which results in dead spaces or neglected spaces. They diminish the attractiveness and proper functionality of dead zones.

Reasons behind dead zones

- **Underutilized Buildings:** Neglected facades with lack of activities can create dead zones.
- **Poorly designed public spaces:** Public spaces with less amenities like seating, interactive activities or without proper pathways, lack in landscaping leads to failure to attract users and can create dead zones.
- **Area use:** Underutilised areas or lack of landscaping can lead to creating dead zones.
- **Inadequate Connectivity:** Areas in district centers that have not been connected to other parts of the district centre properly can be overlooked or avoided by people both physically and visual connectivity.
- **Lack of Mixed Uses:** Some district centres serve single functions like business or residential and can create dead zones outside for certain periods. Mixed-use development can create activity zones throughout daytime and night time.
- **Green Area:** If the green areas are not maintained properly then users would prefer to avoid the green area due to which it can cause dead zones.

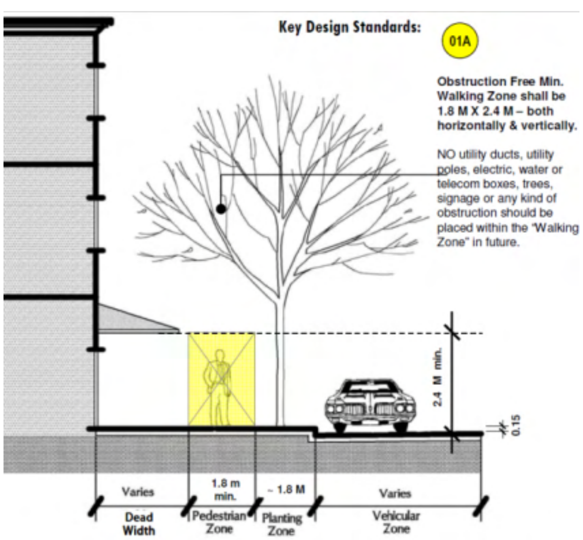

*Figure SEQ Figure * ARABIC 3 Vehicular zone with pedestrian and planting zone (Source: UTTIPEC)*

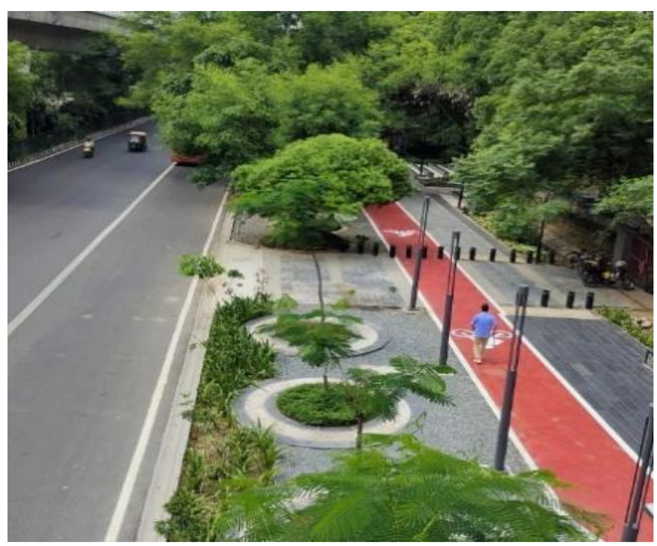

*Figure SEQ Figure * ARABIC 2 Moti bagh streets (Source: oasis designs)*

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CASE STUDIES

Parameter	**Netaji Subash Place**	**Bhikaji Cama Place**	**Nehru Place**	**Rajendra Place**	**Saket District Centre**	**Common Challenges**
Vehicular & Pedestrian Movement	Well-defined pedestrian and vehicular movement, street vendor on paths and not maintained	Vehicular movement only on periphery; pedestrian areas blocked by vendors; poorly maintained.	Movement restricted; central space acquired by vendors; not maintained.	Defined paths but encroached by vendors; not maintained.	Well-maintained movement paths; some encroachments by vendors.	Vendors occupying pathways; congestion due to on-street parking.
Landscape & Streetscape	Ornamental landscaping by buildings; lacks street furniture.	Landscaping by buildings; lacks seating; public gym provided.	Central landscape with seating integrated.	Streetscape lacking; some buildings have ornamental gardens.	Maintained landscapes; lacks seating along paths.	Inadequate seating; poor landscape integration.
Public Interactive Spaces	Eateries present but no sitting; minimal interaction zones.	Plaza with eateries; lacks sitting spots.	Open area for movement only; lacks interactive functions.	Park at rear of building rarely used; inactive public space.	Active plaza with varied seating and social elements.	Lacks public interaction areas; few social seating spots.
Dead Zones	Lack of landscape & interaction led to dead zones.	Dead-end corridors present.	Poorly maintained areas becoming inactive.	Poorly connected rear zones create inactivity.	Few dead zones remain despite efforts to avoid them.	Poor landscape design causes inactive/dead zones.

RECOMMENDATIONS:

1) **A proper area can be designated for street vendors**

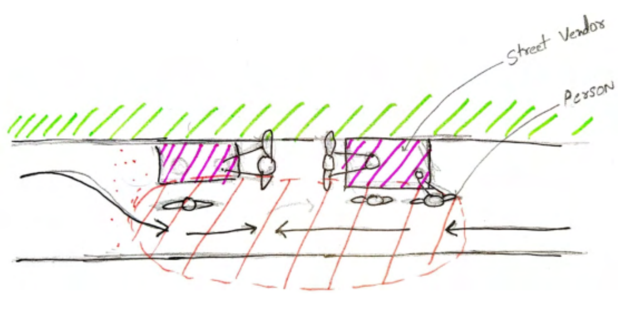

*Figure SEQ Figure * ARABIC 5 Streets acquired by vendors (Source: Author)*

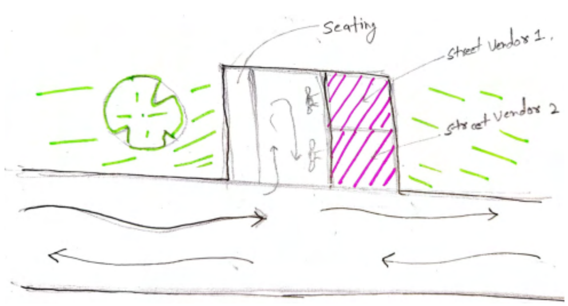

*Figure SEQ Figure * ARABIC 4 Place allotted for street vendors (Source: Author)*

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2) Incorporation of Street furniture's for users or pedestrian

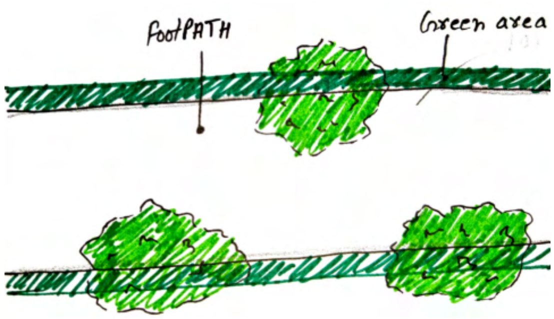

*Figure SEQ Figure * ARABIC 7 Pedestrian pathways with lack of street furniture (Source: Author)*

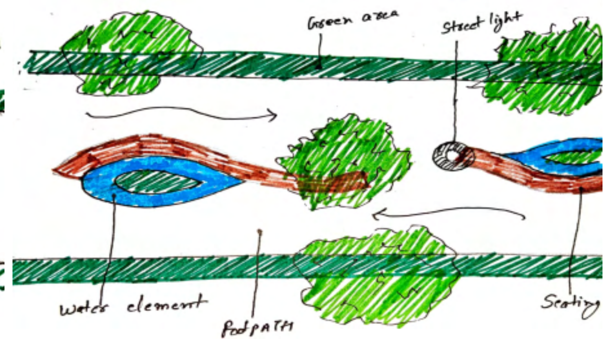

*Figure SEQ Figure * ARABIC 6 Pedestrian pathways with benches (Source: Author)*

3) **Landscaping and streetscape should be incorporated to make any place lively**

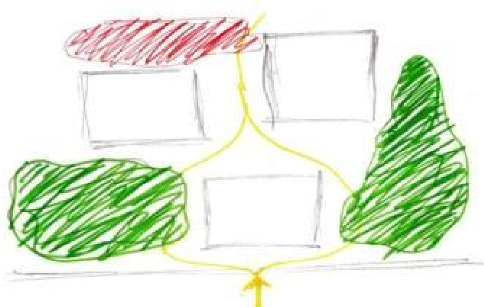

*Figure SEQ Figure * ARABIC 9Without landscape dead zones are formed. (Source: Author)*

*Figure SEQ Figure * ARABIC 8 Avoid dead zones by incorporating landscapes (Source: Author)*

4) Public Interactive spaces can change the environment and quality of life in district centre

*Figure SEQ Figure * ARABIC 11 Water feature used as public interactive (Source: Author)*

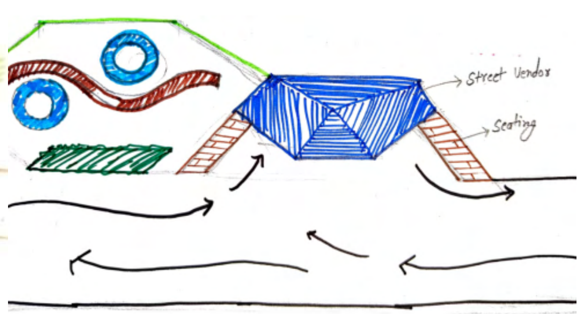

*Figure SEQ Figure * ARABIC 10 Public interactive space added with street vendors (Source: Author)*

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5) **Dead zones can be transformed into place where people can interact.**

Figure 12 Dead zones converted into interactive spaces (Source: Author)

6) **Car parking spaces should be provided along the road sides**

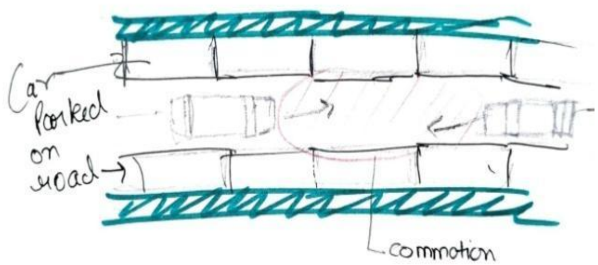

*Figure SEQ Figure * ARABIC 14 Parked vehicles on road creating commotion (Source: Author)*

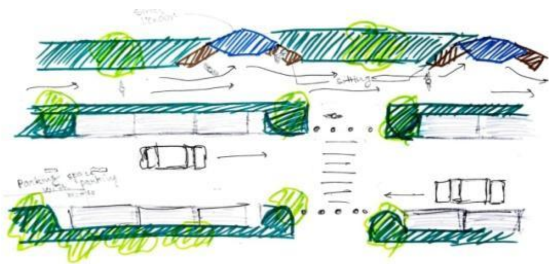

*Figure SEQ Figure * ARABIC 13 Defined parking space and vehicle movement (Source: Author)*

CONCLUSION

District centres are designed to divert the congestion in central business districts by redistributing the population. However, insufficient maintenance in some areas in district centre can leads to negative impact on users. These include the presence of dead zones, inadequate vehicular and pedestrian movement, a lack of landscaping and streetscaping, and insufficient public interactive spaces. Addressing these challenges is crucial for enhancing the overall quality of life in district centres. The recommendations proposed in this study, such as the incorporation of parking spaces along roadsides, the creation of defined areas for street vendors, pedestrians, and vehicles through proper streetscaping and landscaping, are crucial for enhancing the quality of life in district centres. These improvements not only address the current challenges faced by district centres, such as dead zones and inadequate movement of people and vehicles but also promote a more organized and aesthetically pleasing environment. As for public interactive spaces, it is essential to encourage community engagement and to create a connection between users and their surroundings. Public interactive spaces can serve as focal points for social interaction and leisure, making district centres more vibrant and welcoming. The District Centre's quality of life may be improved by maintaining the stated fundamental parameters in an appropriate manner, as well as conducting a thorough study and making recommendations. This study is conducted in such a prophesied manner, the specific district centre will become a potential district centre for that area, district, state, and country.

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ISBN 978-93-342-4408-3

Changing Urban Scenario & Impact On Development Control Norms

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Abstract

Bye laws serve as the backbone of planned urban development, providing guidelines and regulations to ensure orderly growth and optimal land use within cities and towns. However, as urban landscapes evolve and land values soar, the need for periodic revisions to bye laws becomes increasingly apparent. This article delves into the multifaceted nature of bye laws, exploring their significance in the context of augmented Floor Area Ratio (FAR) in use premise.

Augmented Floor Area Ratio (FAR) and is implications

Floor Area Ratio (FAR) plays a pivotal role in urban development, governing the permissible density of construction on a given plot of land. As cities expand and populations surge, there arises a pressing need to leverage FAR to its fullest potential while balancing the requirements of parking regulations, amenities, and services. The augmentation of FAR brings forth a myriad of considerations, particularly concerning the preservation of open spaces, adequate ventilation, and the overall environmental impact of increased building density.

AIM

The aim of writing this paper is to understand the relation between growing FAR ,Use Premises ,Use Zones and their implications (physical, social, psychological) on built Environment.

OBJECTIVES

To achieve the above aim, following objectives have to be worked upon

1. To accommodate natural growth of families and migrated population.
2. To control commercial & mixed use of land.
3. To achieve optimum utilization of land.
4. To save Environment for a healthy human habitation.

Case Studies

- **West & South West Delhi**

Paschim Vihar, Janak Puri, Rajouri Garden, Meera Bagh, Punjabi Bagh, neighboring colonies & Dwarka

Since their inception and over the period of time, have taken the shape with Commercial and Mixed Land Use streets making it difficult for the original owners to live there. Enhancement of FAR rates from 2006 are being charged and accumulated in "Escrow" amounts for upgradation of physical infrastructure whereas on ground, nothing concrete has happened. General public is not aware of the same. They are forced to reside in upper floors and share common or separate compromising parking spaces.

Mixed Land Use Street

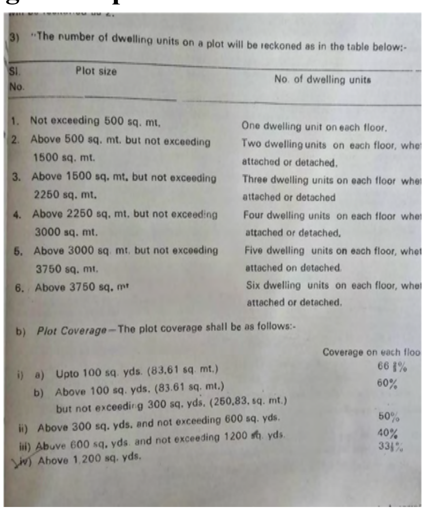
ISBN 978-93-342-4408-3

Club Road, Punjabi Bagh, New Delhi.

Out of 80' RoW, only 30' is left for moving vehicles on both sides, remaining 50" occupied by vehicles on both sides

Analysis, findings and Discussions.

Changing Development Norms



3) "The number of dwelling units on a plot will be reckoned as in the table below:-

Sl. No.	Plot size	No. of dwelling units
1.	Not exceeding 500 sq. mt.	One dwelling unit on each floor.
2.	Above 500 sq. mt. but not exceeding 1500 sq. mt.	Two dwelling units on each floor, whe[ther] attached or detached.
3.	Above 1500 sq. mt. but not exceeding 2250 sq. mt.	Three dwelling units on each floor whe[ther] attached or detached
4.	Above 2250 sq. mt. but not exceeding 3000 sq. mt.	Four dwelling units on each floor whe[ther] attached or detached.
5.	Above 3000 sq. mt. but not exceeding 3750 sq. mt.	Five dwelling units on each floor, whe[ther] attached on detached.
6.	Above 3750 sq. mt	Six dwelling units on each floor, whe[ther] attached or detached.

b) *Plot Coverage*—The plot coverage shall be as follows:-

		Coverage on each floo[r]
i)	a) Upto 100 sq. yds. (83.61 sq. mt.)	66 2/3%
	b) Above 100 sq. yds. (83.61 sq. mt.) but not exceeding 300 sq. yds. (250.83. sq. mt.)	60%
ii)	Above 300 sq. yds. and not exceeding 600 sq. yds.	50%
iii)	Above 600 sq. yds. and not exceeding 1200 sq. yds.	40%
iv)	Above 1.200 sq. yds.	33 1/3%

Bye Laws 1983

SPECIFIC PREMISES

Residential Plot-plotted Housing

Maximum ground coverage, F.A.R., number of dwelling and maximum height for different size of residential plot shall be as per the following table.

Sl. No.	Area of the plot (sqm.)	Max. ground coverage (percentage)	FAR	No. of dwelling units	Maximum height in metre
1	2	3	4	5	6
1.	Below 50	75	150	1	8
2.	50 to 100	66	180	2	11
3.	Above 100 to 250	60	160	3	11
4.	Above 250 to 500	50	140	3(4)	11
5.	Above 500 to 1000	40	100	5(7)	11
6.	Above 1000 to 1500	33.33	83	5(7)	11
7.	Above 1500 to 2250	33.33	83	7(10)	11
8.	Above 2250 to 3000	33.33	83	9(13)	11
9.	Above 3000 to 3750	33.33	83	11(16)	11
10.	Above 3750	33.33	83	13(19)	11

(i) Minimum size of the residential plot shall be 32 sqm. however, in case of Government sponsored economically weaker section schemes, size could be reduced further.

The permissible maximum covered area on ground floor and FAR shall in no case be less than the permissible covered area and FAR for the largest size plot in the lower category.

(ii) In case of residential plots above 250 sqm. facing 24 m and above road, and where already 3 storeys and a barsati was permitted, (as per density calculated in the sanctioned layout); (a) the FAR shall be increased by the maximum ground floor coverage (b) maximum height shall be 14 m and (c) the number of dwelling shall be as given in the brackets.

(iii) The mazzanine if constructed shall be counted in the FAR.

(iv) The basement in case of plotted development shall be under the ground floor and maximum to the extent of ground floor coverage subject to the condition that minimum of 2 m distance shall be kept from the adjoining plot.

(v) For plots above 250 sqm and upto 500 sqm maximum of 3 servant quarters and for plots above 500 sqm maximum of 6 servant quarters shall be permitted.

Bye Laws 1990

Glance at the tables shows that there has been an enhancement of the DU's in different categories thereby increasing pressure on physical infrastructure. Augmentation of services has not kept pace with the increase in population thereby disturbing the micro environment at the ground level.

Due to paucity of land and to accommodate increasing population density, development Control Norms are revised from time to time reduction in space standard and enhancement in FAR Residential plotted developments. It is practical with Service Lanes but where back-to- back plots are there, it is difficult to design. As professionals, it is imperative to ensure that rear setback or open space conforms to requirements, even after plans are sanctioned. This guarantees that adequate air circulation, natural light, and ventilation are maintained.

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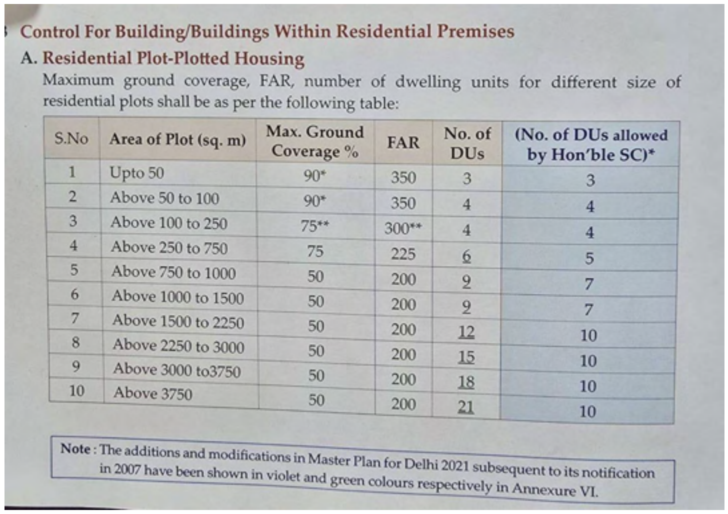

Control For Building/Buildings Within Residential Premises

A. Residential Plot-Plotted Housing

Maximum ground coverage, FAR, number of dwelling units for different size of residential plots shall be as per the following table:

S.No	Area of Plot (sq. m)	Max. Ground Coverage %	FAR	No. of DUs	(No. of DUs allowed by Hon'ble SC)*
1	Upto 50	90*	350	3	3
2	Above 50 to 100	90*	350	4	4
3	Above 100 to 250	75**	300**	4	4
4	Above 250 to 750	75	225	6	5
5	Above 750 to 1000	50	200	9	7
6	Above 1000 to 1500	50	200	9	7
7	Above 1500 to 2250	50	200	12	10
8	Above 2250 to 3000	50	200	15	10
9	Above 3000 to3750	50	200	18	10
10	Above 3750	50	200	21	10

Note : The additions and modifications in Master Plan for Delhi 2021 subsequent to its notification in 2007 have been shown in violet and green colours respectively in Annexure VI.

Bye Laws 2016

Building regulations specify minimum space standards for residential plotted or group housing developments, emphasizing the importance of adhering to these standards throughout the lifespan of the structure. However, there's room for creative thinking in determining the sizes of larger rooms, kitchens, bathrooms, powder rooms, utility areas, balconies, and other spaces.

Another observation reveals that in instances where group housings have availed the benefits of increased FAR, the architectural elevations have suffered, leading to a decline in the overall environment. All-encompassing wrap-around balconies, mandated by bylaws, serve little purpose and instead occupy unnecessary space, detracting from the aesthetics for passersby. While the increased FAR may enhance room sizes, kitchens, and bathrooms, it should not come at the expense of the surrounding environment. Therefore, it's crucial to leverage FAR benefits while prioritizing harmony with the surroundings.

- With the provision of stilt Parking, issues are partially solved cost of growing no. of domestic vehicles as compared to space provided.
- Shortage of physical infrastructure facilities & services.
- Increase in population density, earlier 5-6 person's were residing in one plot, now 20-25 in 4 storeyed residential plotted developments.
- Monotonous facades, which need upgrading.
- Not to cope up with such Environment, people are moving to ncr/ other places where such issues have not cropped up

Group Housings with wrapped around Balconies

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Monotonous Facades (Residential Plotted Developments)

Banquet halls in Industrial Premise

Conclusions

To be precise, space for commercial activities be allowed as per five tier system of Commercial Areas and as per need of the society, for e.g. Activities which are not of prime importance may be avoided and Banquets / similar activities be allowed in convenience Local and community Shopping centres.

Allowing permissions open Public and Semi-public activities like pre-primary schools, nursing homes,

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clinic, pathology lab, Guest houses, banks Fitness, cooking centre and to convert Industrial premises into Banquet Halls ,Hospitals and Group Housings need a serious thought/ concern. Opening of above activities has resulted in degradation of physical infrastructure and enhancing parking problems.

Are economical, sociological, geographical, environmental and psychological aspects taken into consideration before allowing such permissions?

In navigating the complexities of urban development, bye laws serve as invaluable tools for shaping the built environment and fostering sustainable growth. However, their efficacy hinges on adaptive revisions and a nuanced understanding of evolving urban dynamics. By striking a delicate balance between regulatory compliance, creative design solutions, and environmental stewardship, cities can harness the full potential of augmented FAR while preserving the intrinsic charm and functionality of their urban landscapes.

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ABOUT- AAPP

The rapid evolution of architecture and urban planning presents new opportunities to integrate cutting-edge design, sustainable practices, and innovative technologies. In the wake of these advancements, it is essential to explore how these concepts intersect and shape the future of built environments. This online national conference aims to share the insights of the thought leaders, researchers, professionals, and academicians on the integration of innovation, sustainability, and design within the field of architecture and urban planning.