Conference Proceedings

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NCSAPT-2024

Bharati Vidyapeeth (Deemed to be) University College of Architecture, Pune
National Conference on
Sustainability in Architecture, Planning and Technology
NCSAPT-2024
23rd -24th February 2024

Prof. Dr. Priya Bangle **Professor** **Co-Convenor - NCSAPT 2024** **BVDU College of Architecture, Pune**	**Prof. Mukta Latkar-Talwalkar** **Vice-Principal,** **Convenor - NCSAPT 2024** **BVDU College of Architecture, Pune**	**Prof. Dr. Kavita Murugkar** **Principal,** **BVDU College of Architecture, Pune**

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Principal's Note

Celebrating Excellence: National Conference Proceedings 2024

Dear Esteemed Colleagues and Participants,
It brings me immense joy to announce the publication of the National Conference Proceedings 2024, encapsulating the rich tapestry of knowledge and insights shared during our recent conference on sustainability in architecture, technology, and planning.

The resounding success of this year's conference, marked by enthusiastic participation from esteemed scholars and practitioners hailing from all corners of the country, is a testament to our collective commitment to advancing the frontiers of knowledge and practice in our respective domains.

I am particularly delighted by the exceptional quality of papers presented, each offering valuable perspectives and solutions to the pressing challenges facing our society in the realms of sustainability and development. Your dedication to scholarly inquiry and innovative thinking has undoubtedly enriched our understanding and inspired action towards a more sustainable and equitable future.

I extend my heartfelt congratulations to the organizing faculty team for their tireless efforts in orchestrating a truly remarkable event. Their vision, diligence, and unwavering commitment to excellence have been instrumental in making this conference a resounding success.

I would also like to express my sincere gratitude to the management for their steadfast support and encouragement in nurturing such initiatives. It is through their unwavering commitment to academic excellence that we are able to convene gatherings of this magnitude and impact, driving positive change in our communities and beyond.

As we celebrate the culmination of yet another fruitful chapter in our academic journey, let us carry forward the spirit of collaboration, inquiry, and innovation that defines our institution. May the insights shared in these proceedings continue to inspire and inform our collective efforts towards building a more sustainable and resilient world.

With warm regards,

Prof. Dr. Kavita Murugkar
Principal
BVDCUCOA, Pune

Convener's Note

Namaskar,
It is with great pleasure that we publish this Conference Proceedings for the National Conference on Sustainability in Architecture, Planning and Technology 23-24

N.D.C. 3.0 – National Conference on Sustainability in Architecture, Planning and Technology 23-24 marks our third successful attempt, as an Organizing Team, in getting Sustainability enthusiast and researchers together on a platform to present their research regards various Sustainable aspects related to Architecture, Planning and Technology. I hope presenting your Research on this platform and getting valuable feedback and reviews from Invited Experts, Session Chairs and Paper reviewers have qualitatively added to your research Journey.

The Pandemic compelled us to conduct the Conference in an Online mode in 2020 which went hybrid in 2024, in its 3rd cycle, with many physically presenting their Research at our Institute in Pune and still some, preferring to present online for the opportunity it offers. Participants from various parts of the country have always been a feature of the conference showing our efforts to ensure Sustainability concerns reach all, across the country.

I very humbly thank the Management of Bharati Vidyapeeth Deemed tobe University for their faith in us and their wholehearted support in the planning and conduction of the conference. I also acknowledge the efforts of my Co-Convenor and the Organizing team who have year after year been supporting and contributing to a smooth conduction. I hope in years to come the Conference gets the same enthusiastic response and participation from all of you and all those who value a sustainable approach to all things planned and designed.

See you all again!

With Best Wishes,

Professor Mukta Latkar Talwalkar
Vice-Principal.
BVDCUCOA, Pune
Convenor,
N.D.C. 3.0, N.C.S.A.P.T 23-24

Sponge Cities: A Resilient Approach to Urban Living for Disaster Management.

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Abstract:
With increasing challenges due to natural disasters, and climate change, "Sponge Cities" has emerged as a ground-breaking solution for effective disaster management. The main goal of building these cities is to limit the impact of floods and increase the overall resilience of urban cities. These cities prioritize sustainable water management, steering away from traditional drainage-centric approaches that often create water scarcity during extreme weather events. Sponge Cities actively absorb water through innovative features like rooftop gardens, permeable roads, rainwater harvesting, and strategically placed blue and green spaces such as ponds, lakes, and parks. These elements prevent flooding and address water scarcity concerns by efficiently storing and distributing water resources. These components absorb rainwater and reduce surface runoff by acting as natural sponges. Green areas also contribute to the visual appeal of urban landscapes, improve air quality, and promote the well-being of city dwellers in addition to flood avoidance. Pioneered by China, Sponge Cities have been successfully implemented in various urban areas, significantly reducing flood risks and creating more livable and sustainable environments. Beyond flood prevention, these cities enhance urban landscapes, contribute to the well-being of people, improve air quality, and reduce the harsh effects of climate change. Residents play a crucial role in transforming their city into a sponge city by actively participating in public awareness and educational initiatives, engaging in community-driven efforts, and supporting public-private partnerships. These collective actions foster a more sustainable and enjoyable urban environment.
In summary, Sponge Cities represent a crucial shift in disaster management, offering a sustainable approach to urban planning.

Keywords:
Sponge City, Flooding, Sustainable, Urban Planning

Introduction

Flooding is the most common and prevalent natural disaster in the world, wreaking havoc on lives and the economy alike. Recent global environmental concerns are primarily the result of intensified human activity, fast population increase, and hastened urbanization. The effect of urban storm water runoff

on the urban environment has become one of the more pressing concerns among these challenges. Urban flooding disasters are caused by a combination of causes, including rainfall patterns, the extent of urban development, and the insufficiency of drainage systems. When sewage pipes and storm water pipes get tangled and misconnected, it causes sewage water to flow into urban water channels, polluting the water and degrading the water management system. There's a critical need to create an effective system for water management and prevent waterlogging. The concept of the "sponge city," introduced in 2013, aims to confront urban water management challenges in China and build a balanced connection between people, water, and the city. The concept involves adopting a nature-based and grey solutions approach to address issues like urban waterlogging, enhance water storage and discharge capabilities, improve water quality, and mitigate heat island effects. This is achieved through the implementation of six technical measures: "infiltration, retention, storage, purification, utilization, and discharge." Wuhan took a significant step in 2015 by initiating the sponge city demonstration project, which includes two demonstration areas and 288 pilot projects.

The remarkable success of the Wuhan Sponge City Program highlights its effective waterlogging prevention measures and underscores the potential of nature-based solutions. In the summer of 2020, despite facing intense and record-breaking precipitation during a prolonged rainy season, Wuhan experienced no significant waterlogging issues. The implementation of sponge projects played a crucial role in significantly alleviating water logging problems in the city. The concept of Sponge Cities involves transforming urban areas and infrastructure, including parks, streets, and buildings, into entities that can "act like sponges." This innovative approach to urban management enables cities to naturally absorb, store, and purify rainwater, addressing waterlogging concerns, preventing urban flooding, enhancing water storage and discharge capacity, improving water quality, and mitigating heat island effects. The integration of both nature-based and grey solutions forms the core of the sponge city concept.

Looking beyond Wuhan, Chennai, India, is actively pursuing the transformation into a sponge city by implementing cutting-edge water management

techniques aimed at reducing urban flooding. Similar initiatives are underway in Kochi's City Centre, focusing on ecological balance improvement and water conservation to create a sponge city. These endeavors reflect a global trend toward sustainable urban development, with the sponge city model playing a pivotal role in reshaping urban landscapes and fostering a more resilient and environmentally conscious approach to urbanization.

1. Benefits of Sponge Cities –

1) Captures and reuses rainwater.
2) Enhances overall water quality.
3) Lowers the likelihood of floods.
4) Lessens issues with travel and traffic.
5) Lessens the severity of urban heat islands.
6) Rainfall can be directed towards a canal, reducing the frequency of flash flooding. Prolonged periods of rain can also be managed.

2. The implementation of the Sponge City concept:

Implementation relies on four fundamental principles, each contributing to the sustainable and efficient management of water resources within urban environments.

a) Optimizing City Surfaces to Improve Rainwater Absorption and Retention: This first principle deals with improving the absorption and retention of rainfall. This procedure is essential for managing and lowering storm water runoff and providing a sustainable water source. Trenches under roadways and other ductile iron pipe systems provide an advanced rainwater-gathering method. Comprehending hydrological properties is essential for the seamless integration of urban drainage systems with natural water networks, guaranteeing an all-encompassing strategy for water resource use.

b) Water Ecology Management:

A vital component of the Sponge City idea, the second principal concerns water ecology management. This entails incorporating ecological waterfront design and putting self-purification technologies into place. Water purification is greatly aided by restoring aquatic habitats through healthy landscapes that are impacted by soil, plants, microbes, and water flow processes. Artificial and natural ecological shoreline designs are essential to prevent riverbank erosion, highlighting the significance of balancing urban growth with environmental sustainability.

c) Green Infrastructure Utilisation:

The third principle emphasizes the role of green infrastructure in storm water purification, restoration, adjustment, and reuse. Green infrastructure, marketed to preserve the environment and promote sustainable urban growth, includes natural solutions, including filter drains, green roofs, and detention basins. The advantages of integrating biological features into urban landscapes are numerous, as evidenced by the benefits of green roofs, which include lowering storm water runoff, enhancing air and water quality, and lessening the impact of the urban heat island effect. Rain gardens and bioswales are two examples of bioretention systems that use soil layers and living plants to filter pollutants from runoff.

d) Permeable Pavement Incorporation:

The fourth principle promotes using permeable pavements in urban road building to improve the city's overall permeability and water management. This state-of-the-art method allows for enhanced rainwater infiltration and groundwater purification using absorbent materials in ground pavement construction. Consisting of continuous voids, previous concrete facilitates air and water movement, mitigating flooding and aiding in environmental restoration. The Sponge City framework highlights the several advantages of urban permeable pavement technology, including noise reduction and ecological soil enhancement.

In summary, based on these four guiding principles, the Sponge City idea offers an all-encompassing and scientifically sound method of managing urban water resources by fusing sustainable practices, engineering, and ecology to improve urban settings.

2.1 Global Success in Implementing the Sponge City Concept:

Drawing inspiration from international approaches like "Low Impact Development" (USA), "Water Sensitive Urban Design" (Australia), "Sustainable Urban Drainage Systems" (UK), and "Low Impact Urban Design & Development" (New Zealand), China introduced the innovative "sponge city" concept to redefine the interplay between people, water, and urban environments. In 2013, Chinese President Xi Jinping emphasized the need for cities to be constructed as absorptive entities, utilizing natural forces to accumulate, infiltrate, and purify rainwater, resembling a sponge in a novel form of urbanization. Since then, the "sponge city" concept has gained prominence.

The widespread adoption of the Sponge City model, characterized by holistic urban planning, has effectively addressed challenges such as urban flooding, water resource management, and sustainable development in various countries. The Sponge City model's practical application is context-specific and calls for community involvement, infrastructural development, and regulatory changes.

3. Sponge City Construction:

A Systematic and Realistic Approach to Urban Water Management

a) Preservation of the original rivers, lakes, marshes, ponds, and ditches is foundational to urban

development. This approach involves meticulous efforts to maintain and protect these natural features, respecting the existing biological framework. This initial step sets the stage for sustainable urban growth, emphasizing the importance of retaining the city's original ecosystem.

b) Regular systematic ecological restoration and repair activities are integral to address any harm inflicted on water bodies and other natural habitats. A designated percentage of ecological space is consistently preserved, and specialized water ecological infrastructure is developed to support ongoing restoration efforts. This measure ensures the continual renewal and maintenance of the urban ecosystem.

c) Incorporating low-impact development into the construction process is crucial to regulating the intensity of urban development while minimizing disturbances to the natural aquatic ecosystem. Strategic excavation and improvement of rivers, lakes, and ditches increase the number of water areas, aiding in the collection, infiltration, and purification of precipitation. This expands the urban "sponge" both quantitatively and qualitatively.

d) Managing urban precipitation-generated surface runoff is a key focus, emphasizing robust drainage systems to ensure appropriate water flow. The installation of permeable zones is essential for superficial infiltration. A comprehensive flood disaster risk management system is implemented, prioritizing safety and adaptive measures for building mitigation, personal hedging, and disaster prevention.

e) Sponge city construction actively supports sustainable urban growth through these meticulous methods, facilitating the coexistence of urbanization and the preservation of natural water ecosystems. This approach ensures resilient and environmentally conscious city development. By correctly implementing the sponge city concept, it has the potential to lower carbon emissions, contribute to the fight against climate change, enhance water quality, and reduce the frequency and intensity of floods.

4. Wuhan Sponge City Program: Achieving Harmony Among People, Water and City:

Wuhan, located in central China, is well-known as the “city of one hundred lakes” and has abundant water resources and extensive water systems. However, water management and waterlogging prevention in Wuhan is challenging. Wuhan has suffered from waterlogging for years mainly due to the low-lying built-up area and the uneven distribution of precipitation.

Wuhan is one of the sponge pilot cities in China. The sponge infrastructures applied in Wuhan include nature-based solutions, such as rain gardens, grass swales and bioretention facilities, and gray infrastructure, such as permeable pavements, infiltration trenches, and rainwater storage modules. The target of the Wuhan Sponge City Programme is set as 20% and 80% of the urban area should achieve the sponge city requirements by 2020 and 2030 respectively and absorb 60%-85% of the annual rainfall.

Several key points lead to the success of the Wuhan Sponge City Programme:

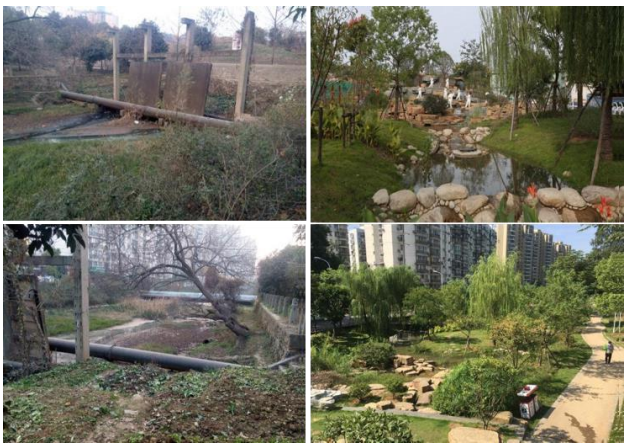
1) Applying whole-process management in waterlogging prevention;
2) Integrating sponge projects in Wuhan Comprehensive Planning with the collaboration of different city departments;
3) Developing localized strategies and technical standards;
4) Establishing a fund-raising mechanism and attracting social participation for risk- and benefit-sharing.

4.1 Case Study 1
Qingshangang Wetland Sponge Project
Area: 0.76 km2
Location: Qingshan District (Demonstration Area)
Background - The river channel in Qingshangang area was congested with silt and wastes, which reduced the drainage capacity and water mobility. The sewage outlets were discharged directly into the water body, leading to heavy pollution and eutrophication in the channel. The deteriorated water ecosystem also caused severe biodiversity loss. Moreover, the open space around the area was constructed into shanties and vegetable farmlands, so the landscape quality of the area was extremely poor. Therefore, this sponge renovation project aimed at enhancing the drainage capacity, improving the ecological environment of the area and forming a connected public recreational park.

Plan & Design- The Qingshangang sponge project was designed to capture 85% of the annual rainfall on-site and reduce at least 70% of water pollution. To fulfill the targets, it was important to divert the sewage and rainfall pipes and control pollution. The pollution control employed ecological treatments, such as ecological drainage, floating islands, wetland and subsurface wetland, and taking advantage of the 8-meter elevation to treat combined sewer overflows. In the green space along the canal, the sewage water is discharged through sponge facilities rather than going directly into the water bodies. The rainwater can be reused for green areas. As for the water environment, channel dredging was conducted to improve water quality and flow capacity, and aquatic plants were planted to restore the water ecosystem. Besides, the project integrated sponge design into landscape design

with the purpose of enhancing landscape quality. Some streets and residential areas were transformed into sponge-like areas to reduce the pollution at the source. The project has laid out numerous sponge facilities, such as grass swales, rainwater gardens and infiltration pavement and rainwater storage modules, in the project area.

Results - Through different sponge measures, the black and odorous water bodies were eliminated and the drainage capacity in the catchment was significantly improved, which alleviated the waterlogging issue effectively simultaneously. The main indicators of the sponge project have reached the goal of the annual runoff control rate of 85% and achieved the flood control standard of effectively coping with a 50-year rainstorm. This project is a demonstration project, driving the renovation of surrounding areas. The urban greenways connecting surrounding parks have formed an interconnected landscape pattern, creating a recreational area for citizens.



F1: Before and after construction of Qingshangang Wetland Sponge Project.

4.2 Case Study 2

The Sponge Project in the Gangcheng No.2 Middle School

Area: 0.02 km^2

Location: Qingshan District

Participating units: Hubei Design Branch of Pan-China Construction Group Co. LTD

Background - The school is located in a low-lying area with low quality of pipes, leading to poor discharge capacity of the internal drainage system and a high risk of waterlogging. The school is at the source of the catchment area with the misconnection of rainwater and sewage pipes and initial storm water runoff pollution, which cause threats to the water quality in the downstream water bodies. Thus, point and nonpoint source pollution should be reduced at the source. The water consumption of school roads and green space is relatively large. The rainwater recycling and collection can realize rainwater recycling utilization and save water resources. The landscape quality in the school is relatively low, so the environment should be optimized to improve the satisfaction rate of the school.

Plan & Design-In this sponge renovation project, the design standard was comparatively high as the school was a high-risk area for waterlogging. The goal for the annual rainfall capture ratio was 80% and the recurrence interval for storm sewer design was 5 years. Different solutions were applied to resolve different problems. The project designed the renovation of the misconnected storm water and sewage pipes to completely separate rainfall and sewage. The storm water pipes were planned to tackle issues of the blocked storm water pipes and the poor discharge capacity. Clearing and dredging the open channel was critical for siltation and poor water quality. Regarding water logging issues, a storage tank was constructed in the school to collect rainwater and pump it to open channels to increase the water drainage capacity. Moreover, this sponge project planned to replace the current storm water inlets or construct new ecological rainwater drains to reduce pollution and increase the drainage efficiency. Also, sponge infrastructure, including a rain garden, permeable pavement for pedestrians, a previous playground and parking area, leveled flower beds and ecological dry creek, were built to slow down the discharge speed and reduce the pressure for drainage facilities. The project also conducted unified management of sponge landscape patterns to solve the problems of unreasonable landscape layout, the mixed flow of people and vehicles, and poor landscape quality (bare loess). To tackle the issue of the shortage of parking spaces at school, a permeable parking space was built to the west of the table tennis field and to the north of the teaching building. In addition, the project also constructed a sponge publicity board at school for sponge education.

Results

This sponge project has constructed a 400m rainfall storage tank and 4 water pumps on campus. The collected rainwater can be used for campus greening and road flushing to reuse rainwater. After construction, the waterlogging points would not exceed 15 cm and would disappear in half an hour. No waterlogging happened during the storm event in August 2017 when the hourly precipitation reached 113.5mm.

F2: Before and after construction of the sponge project in the Gangcheng No.2 Middle School

During project construction, rainwater and sewage were separated, the overflow of sewage on rainy days was reduced, and the impact on the downstream sewage treatment facilities was successfully reduced. The project also eliminated water logging issues in the area with the construction of new rainwater pipes and gutter inlets. Regarding the landscape sponge renovation, the sponge indexes were effectively improved through the construction of low-impact development facilities. Other results will come out after the completion of the entire project.

5. Challenges of Urban Flooding in Kolhapur, Maharashtra:

During the months of July & August 2019, 2021 Kolhapur districts experienced extreme floods for long durations. Heavy losses to life, property & crops etc. had been reported. Different opinions at various levels were put forth concerning these flood events. Sangli & Kolhapur districts faced heavy flood situations in the past also & floods of 2005 & 2006 were noteworthy. However, the 2019 flood event was comparatively much more severe which lasted more than a week & losses experienced were also on a higher scale. The reason behind this kind of flood situation is very straightforward: the heavy rainfall happened in the Krishna River basin. So that the excessive amount of water released from Koyana dam. This water did not pass down through Almatti dam properly. Hence a flood situation was generated.
Kolhapur, located in the western part of Maharashtra, faces unique urban flooding challenges due to its distinctive climate characterized by heavy rainfall from June to September.

As the largest city in south Maharashtra, Kolhapur has witnessed substantial population growth since the late 19th century, particularly in the post-independence era. This growth has strained resources, resulting in issues related to infrastructure, water management, and settlement patterns. The years 2019 and 2021 witnessed severe flooding, displacing thousands and causing extensive infrastructure damage.

Fig 3 -

F3:

During floods, key infrastructure, especially roads, plays a vital role. Data obtained from photographs aids in evaluating the impact and preparing for contingencies.

5.1 Impact on Panchganga River System:
The Panchganga river system, a vital resource for Kolhapur, has suffered from the consequences of rapid urbanization. Activities such as artificial mining, valley development, irrigation, and dam construction have altered the natural flow of the river. Industrialization and agricultural expansion, including the establishment of sugar refineries, have led to deforestation in the river basin and encroachment on riverbanks. Primary causes of recurrent floods in Kolhapur include heavy rainfall, development in floodplains, and the vulnerability of towns along the Panchganga River and its tributaries. Monsoon rainfall, geography, river flooding, and rapid urbanization with inadequate storm water drainage collectively contribute to an elevated risk of flooding.

Reduced discharge carrying capacity of river Panchganga due to siltation, vegetation growth and encroachments further delayed the reception of floods. The lateral slope of the floodplains is very gentle. The flood plains are almost flat. This has resulted in the spreading of flood water on a larger area on both the banks of the river.

5.2 Environmental Consequences:
The urbanization of Kolhapur has resulted in environmental issues such as deforestation, soil erosion, and disruptions to river ecosystems. River siltation, exacerbated by agricultural activities and deforestation, amplifies the risk of floods. The development of roads and communities along riverbanks further heightens the flood danger. Climate change worsens the situation by increasing the frequency and intensity of rainfall, leading to more severe floods. Mitigating flood risks necessitates innovative solutions, including adopting the Sponge City concept, resilient urban planning, and sustainable practices, to ensure the long-term viability of urban areas in the region.

5.3 To transform Kolhapur into a sponge city and improve its water management, residents and local authorities can take several steps:

a) Permeable Surfaces: To reduce surface runoff, porous materials can be used in roadways, walkways, and other surfaces to allow rainfall to seep into the ground.

b) Green Spaces and Urban Vegetation: Creating more parks and gardens, among other green areas, aids precipitation absorption and enhances soil water retention. In addition to improving the urban environment's beauty, vegetation supports biodiversity.
c) Retention Ponds and Wetlands: Building wetlands and retention ponds facilitates collecting and storing rainwater during periods of high precipitation. These natural structures lessen the chance of flooding downstream by serving as makeshift reservoirs.
d) Green Roofs: Planting vegetation on rooftops lowers the urban heat island effect, offers insulation, and aids in the absorption of rainfall. In densely crowded places, green roofs can provide extra green space and aid in the retention of water overall.
e) Rainwater Harvesting Systems: By putting in place these systems, rainwater can be gathered and stored for various applications, including irrigation, non-potable water supply, and groundwater replenishment.
f) Smart Infrastructure: Water management may be improved by combining technology with intelligent infrastructure elements like sensors and monitoring systems. This covers adaptive control methods, early warning systems, and real-time water level monitoring.
g) Community Engagement: A vital component of the Sponge City approach is including the community in water management procedures, educating people about water conservation, and promoting wise water use.

F4:

6. Conclusion

A city designed as a sponge, equipped with features like rain gardens, rooftop gardens, rainwater harvesting, permeable roads, and blue and green spaces, mirrors the absorbent nature of a sponge. This innovative approach, known as the "Sponge City," adeptly responds to environmental changes and manages natural disasters by actively absorbing water during heavy rainfall and releasing it as needed during dry spells. The initiatives associated with Sponge City not only promote sustainable development but also emphasize the importance of green infrastructure by efficiently collecting rainfall for future use and aiding in flood management. Enhancements can be achieved by incorporating underground water tunnels, previous concrete roads, and green building concepts to enhance overall sustainability.

A meticulous sector-wise division of the area, featuring detention ponds with ample holding capacity based on regional rainfall patterns, is crucial for successful implementation. These ponds can serve dual purposes as recreational spaces and water sources, with surplus water easily evacuated through an exit drain connected to the central drainage system.

The Sponge City program exemplifies how nature-based solutions can enhance climate resilience by mitigating the impact of landslides, floods, droughts, urban heat islands, and desertification. Beyond water management, the integration of green infrastructure elements like rain gardens, bioswales, wetlands, permeable pavement, and green roofs also benefits diverse ecosystems.

To unlock its complete potential, the Sponge City approach must be embraced as a fundamental aspect of urban development, and seamlessly incorporated alongside traditional gray infrastructure. Kolhapur's application for Sponge City principles will show remarkable outcomes, including the replenishment of groundwater tables, mitigation of air and water pollution, heightened rainwater collection in dry periods, resilience against flooding, harnessing solar energy, and an overall reduction in heat intensity. Our proposal advocates for the assimilation of Sponge City concepts into Kolhapur's urban planning regulations, highlighting the significance of public awareness, strategic infrastructure investments, and collaborative efforts for successful implementation.

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Loci: Recall and Resilience - Nurturing Sustainable Community Through Community Engagement in Urban Planning

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Abstract:
The study's methodology, which is in line with urban planning, With a focus on the urban nodes, this study explores the complex interactions between memory, sustainability in urban planning, and technological integration. Under the conceptual framework of "Loci," the study uses a unique historical mapping methodology with the goal of revealing the growth patterns and physical attributes that give these cities their individual identities. Acknowledging the critical role that urban nodes play in defining the overall nature of cities, this study broadens its analysis to understand the general traits that are inherent in the urban fabric of Visakhapatnam and Vijayawada. The study aims to illuminate the fundamental relationship between historical narratives, communal memory, and urban design techniques by emphasizing their dynamic interaction. Furthermore, the study makes a compelling case for the application of planning techniques that effectively incorporate resilience and memory into the structure of urban development itself. The study seeks to foster sustainable communities by highlighting the importance of remembering, considering both the material characteristics and the intangible components that greatly contribute to the unique character of these places. Planning principles, emphasizes the critical role that historical narratives play in creating dynamic and sustainable urban settings. This goes beyond simple preservation; it also involves encouraging long-term activities that support social and economic innovation as well as community engagement. The research aims to create cities that are deeply rooted in their historical and cultural contexts, while also being functionally efficient. By attaining this, it hopes to create a more resilient and sustainable urban future by fusing the threads of remembrance with urban planning practices.

Keywords:
Loci; Urban Planning; Urban Nodes; Community Engagement; Sustainable Development.

Introduction

In the dynamic realm of multidimensional cities, Loci states its significance by en-rooting the concepts of “Recall” & and “Resilience” such that The intricate interplay between recall, the ability to draw upon past experiences and lessons, and resilience, the capacity to adapt and withstand challenges, lays the groundwork for sustainable urban development. The loci method is a methodology for memorizing information that involves setting each thing to be recalled at a different place along an imaginary journey. By retracing the same route during the hypothetical excursion, the information can be remembered in a specific sequence. That’s how cities work, Isn’t it?

Even in the era of Google Maps, I still wonder if we can underestimate the recognition of cities and the collective memories associated with them. The undeniable fact is that Cities also function as Human beings, Every City has its smell, color & and soul. And the process to recognize that, inhale it is through the lens of observing the cityscape around you, perhaps the breeze at the terrace, the sweat of the traffic jam, a cup of tea at the bus stop, the spirituality of religious building, Waves near the Beach or just a place that makes you feel yourself.

As an Architect & Now an Urban Planning Student, there’s no way to get out of “Observation in Multi-Dimensional”. I think that’s what we are embedded in.

The loci method employs the concept of visualizing a space in which various recollections can be preserved. Space is frequently a building, a dwelling, or a road that connects many locations. The benefit of this tactic stems from the subconscious capacity to store mental images in Cities.

Further, the research enhances its boundaries towards the role of Collective memory through the process of Loci, to lead to community engagement for Sustainable Development.

1. Conceptual Framework in Community Engagement: "Loci"

Myths about the city are intrinsically linked: If not the "mythical" center of the globe, then what is Jerusalem? Without its Greek and Levantine mythology, what would Alexandria be? Can one experience it without Durrell or Cavafy? How about New York? Rome? Paris? What originated from legends and histories as well as what is true concerning the place?

The way “loci” is linked to memory is the solution for organizing these tales into applications for better city functioning? As a result, in urban planning, it's critical

to create a framework of techniques that lead to sustainable development, of which "community engagement" in sociocultural societies is one of the significant ones.
From The spatial patterns of the city to settlements along the natural resources, or planning along the greens.

F1: Vijayawada City View

Halbwachs (1992) distinguishes between collective memory and history as the active past that shapes our identities and the remembered past to which we no longer have an "organic" relationship. As such, both are publicly accessible social facts, the latter being "living" and the former being "dead. "This is the reason Christine Boyer set out to establish a public environment that permits "the play of oppositions, the existence of randomness, disturbances, dispersions, and accidents" in a fractured and pluralist society in The City of Collective Memory (1996). Both tangible and intangible monuments serve as repositories of collective memory. Conflicted memorials, not to mention colonial monuments repurposed as national symbols, provide evidence of unresolved political debates. It is frequently translated into representations, images that are constantly reframed and recirculated. Memorialization can be selective, and forgetting is therefore a necessary component of it as well. To sum up, memorialization involves a great deal of looking back, whether it is to process trauma or to indulge in nationalist nostalgia. In the modern day, monuments are continuously reimagined to fit certain political objectives, and communal memory functions to validate the conflicting goals of various groups.

The Concepts of modernism, tradition, the nation, and history are intertwined with views on cities, monuments, and memories from throughout the world. The intricate yet crucial connections among monuments, communal memory, and national identity play a vital role. It explores the fundamental ideas and historical context of these relationships, heavily referencing a variety of memory theories developed in the 20th century. It looks into how history is written and how ideas of modernity and history incorporate development.

2. Methodology: Role of Remembrance in Historical Mapping & Urban Nodes

2.1 Significance in Urban Planning

Cities are settings where different facets of historical events are projected and communicated through individual recollections and stories; urban memory can be understood as a manifestation of collective memory that has developed over time within a specific area. This paper examines urban memory as a crucial component of a city's cultural legacy that needs to be recorded and conserved for upcoming generations. The idea of urban memory is introduced in this chapter along with its connections to time and space. It offers an overview of various programs designed to record, conserve, and utilize urban memory and suggests a framework that enables people to engage with urban memory by contributing their memories and viewing those of others, which plays a vital role in Urban Planning.

3.2 Case Studies: Visakhapatnam and Vijayawada
According to Italo Calvino, "Stories are invisible cities, and cities are invisible stories." To construct the new, the architect may have to demolish what came before his designs. Nothing is destroyed by the author. A writer seeks to dismantle boundaries, transcend definitions, and create spaces for one another, whereas an architect seeks to create distinctions, arrange relationships, and define limits. Architecture aims to hang the doors that separate the proclaimed and the undeclared, while literature attempts to carve gateways between them.
The role of the Urban Planner is thereby to balance The relationship between a place and its living memory.

i) Vijayawada, The City of Victory

The second-largest city in the recently created Indian state of Andhra Pradesh, Vijayawada, is a remarkable mosaic of spatial patterns that capture the peculiarities of its geography and population. The city's physical structure is profoundly influenced by these bodies of water, which are located between the Budameru River on the north and the Krishna River on the east and west. A modest range of hills encircles the northern, northwest, and southwestern sections, offering a lovely background to the metropolitan environment. On the other hand, three significant irrigation canals cut through the lush, fertile agricultural plains in the city's center, southwest, and northwest, adding to its agricultural liveliness.

The population of Vijayawada Municipal Corporation (VMC) in the 2001 and 2011 censuses, which reflects the city's expansion, highlights Vijayawada's reputation as a vibrant urban hub. The population of the city increased from 8,45,217 to 10,48,000, mostly due to immigration from nearby towns and natural growth. This flood of varied populations adds to the city's

dynamism and brightness by enriching its cultural fabric. The Spatial Arrangement of the city space replicates the valor by various statues & and utilization of recyclable materials for artifacts & and sculptures at junctions as fountains, further the streets diverge into mostly Y-Junctions, with Oblique directions, that make remembrance of the city convenient & and therefore lead to resilience & loci is followed.

F2: Vijayawada - The Street view

Vijayawada is a city of dynamic urban hubs that encompasses a diverse range of tourist attractions that are harmoniously integrated with the spirit of social solidarity and urban remembering. Bhavani Island, a tranquil haven on the Krishna River, is one of these treasures. Tucked away in the center of Vijayawada, the Island offers guests a peaceful haven that creates a memorable urban experience. Its verdant surroundings and views of the waterfront create a lovely atmosphere for introspection and bonding. The Island is an urban node that represents the city's dedication to social cohesiveness by providing a peaceful setting where residents and visitors alike can make enduring memories amidst the splendor of nature.

F3: Bhavani Island, Vijayawada

Apart from its complex demographics, Vijayawada is a thriving commercial center, best known for its wholesale trade in agricultural products. The city, which specializes in fruits, vegetables, and spices, is essential to regional trade [13]. Furthermore, Vijayawada has a booming industrial environment that includes small-scale iron and hardware companies, clothing production, and vehicle body assembly. The city's industrial strength is demonstrated by the Jawahar Lal Nehru Auto Nagar Industrial Estate, a prominent hub for the automotive sector in Asia. Exploring Vijayawada's spatial patterns is an intriguing project that combines geography, history, and modern urban dynamics. I am an urban and regional planner with a strong grasp of technical planning vocabulary.

ii) Visakhapatnam, The City of Destiny

Heralded as the "City of Destiny," Visakhapatnam tells its story as a port city that is growing quickly and stands out as the most populous and second-largest urban agglomeration in combined Andhra Pradesh. With its modest origins as a small fishing village, the city has grown into a major port, a monument to the natural harbor's transforming potential. Visakhapatnam is becoming a more important economic hub in the region, as seen by the large number of people who have moved there as a result of its increasing industrialization.

The introduction of sectors including steel, fertilizer manufacture, and petroleum refining has resulted in a notable expansion of the city's industrial environment. With the creation of Greater Visakhapatnam in 2005, the city is now ready for a significant development spurt and is positioned for a future in which sustainable practices and urbanization coexist.

The comprehensive approach to the spatial parameters of the city includes the recognizable urban Islands, and settlements along the beach, the driver of the city.
Further, the observation followed by vibrancy in the regular patterned streets as well through wall paintings, and folk arts below the flyover, the colors of the city life along the pedestrians are vibrant enough to add to the liveliness of the city. Utilization of Sustainable techniques for seating spaces at famous junctions like Vizag Square. The remembrance associates collective memory that seeks loci as a concept to recall the places from significant buildings, junctions, urban spaces, & and the soul of the lively city.

F4: Visakhapatnam, Junction (Vizag Square)

Visakhapatnam has developed into a crossroads where the city's past, present, and future collide in the spirit of sustainable development and community involvement.

A comprehensive and environmentally friendly development plan is based on the combination of administrative innovation, industrial prowess, and a dedication to citizen-centric services. The history of Visakhapatnam is not only one of development and expansion, but also a complex narrative intertwined with the strands of its harbor, its people, and an ambitious plan for the future that will ensure its sustainability and long-term success.

F5: Visakhapatnam, Usage of Recyclable Materials at Junctions

3. Interplay Between Memory, Sustainability, and Technology

Memory in humans is spatial. One tool for molding memory is the shape of space. In two senses, a street or other shared area might serve as a hub for communal memory. It can convey collective identity from above through civic spaces, street names, memorial sites, architectural order, and historic preservation; and it can convey the accumulation of memories from below through the tangible and evocative traces left by daily patterns that weave together. The two kinds are practically inseparable. Private lives are acted out in the rhetorical spaces of public symbolism, and national memorial is braided into the soap operas of ordinary existence through street and shop names.

Further, the Collective memory is created by repeated activities involving shared beliefs and viewpoints, as well as by individuals or groups having common memories. It's precisely remembering something in common. History is unique and is preserved by memorization and framing using the external data that is readily available, such as images, dates, events, and works of literature that are authentically associated with the location.

Recalling is analyzed through the lens of cities, promoting social cohesiveness through the efficient use of streets, parks, green spaces, and historic buildings as catalysts for urban efficiency. Recyclable material seating and automatic parking systems are two examples of smart technology that are integrated into cities to make them more memorable and to support sustainable development. The study uses a thorough examination of data from Visakhapatnam and Vijayawada to show how sustainability, urban memory, and technology improvements interact dynamically. This information will help develop future urban planning and development plans.

4. Symbiotic Threads: City Spirits, Loci Recall, Resilience Nexus

When humans draw borders and believe something has value, a space becomes a "place". Over time, several societies develop and remake the area. From beginning to end, the place's identity changes with time. Understanding the dynamic interplay between place identification and mobility in today's dynamic society is becoming increasingly difficult. A way to reach the point when space and time combine is to acknowledge the location identity.

F6: Visakhapatnam, the R K Beach View

The origins are always the city's spirit. Embracing the city's character and the sustainable approach, which promotes community involvement and social cohesion, and then organizing interventions for improved A city moves forward via its resilience. Loci serve as a trigger, or a reminder, to facilitate the transition to sustainable development. Despite its rapid development, the city demands to maintain its authentic identity.

Conclusion

In conclusion, this study provides a nuanced knowledge of the symbiotic interaction between technology, memory, and sustainability in the urban nodes of Visakhapatnam and Vijayawada, which is relevant to me as a spatial planner. Through the use of a special historical mapping methodology and the framework of "Loci," the research explores the physical characteristics and patterns of growth that give each of these cities its own identity. The focus on urban nodes as critical components that shape cityscapes highlights the study's dedication to identifying the universal characteristics present in the urban fabric.

A dialectical comprehension of the relationship between space, time, and human existence becomes crucial in the complex web of urban planning. Our goal as city planners is to create suitable and equitable urban areas, and this requires us to acknowledge the mutually

beneficial relationships that exist between shared experiences, personal behavior, and physical assets. This holistic viewpoint emphasizes the need to go beyond a narrow emphasis on the physical components, realizing that the unique qualities of a location are derived from the dialectical interaction between these aspects. For Example, The photography point of different cities conveys a lot about the story of the city & the remembrance is through such locations, Vijayawada replicating its river-front and history while Visakhapatnam is the story of Vibrancy and liveliness. (Fig 7)

F7: Showcasing the city life in a Frame of Vijayawada (Depicting Riverfront- History) & Visakhapatnam (Depicting Vibrant City Life)

A change from a top-down to a bottom-up approach has been brought about by the growth of ideas about time and location. This approach emphasizes the importance of individual acts and their role in forming place-based traits. A context-based paradigm has emerged as a result of this shift in disciplines relating to geography and social interactions. Innovative approaches, like oral history, make it easier to communicate directly with a variety of communities, giving them a platform to express themselves and building a shared history of both individual and group memories.

The combination of tangible qualities and intangible experiences becomes apparent as we work toward resilient and sustainable communities. Equipped with these insights, spatial planners possess the transformative ability to create urban environments that harmoniously blend the past, present, and future. The method relies heavily on the reciprocity that develops between researchers, professionals, and place users. This reciprocity fosters community engagement, which is crucial for sustainable development.

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Strengthening Urban Habitat Risk Resilience An integrated approach to mitigate increasing climate change effects – Urban Heat Island, Urban Floods and Air Quality Index.

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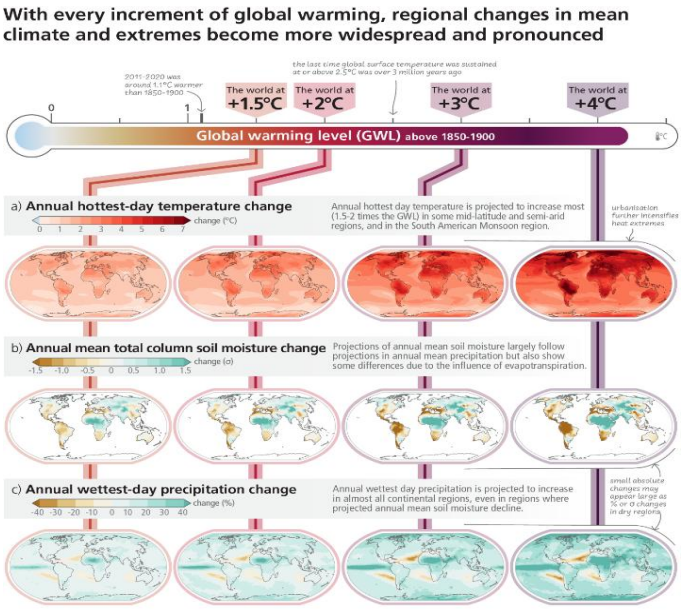
Abstract:
Urbanization, driven by rapid population growth and extensive infrastructure development, has aggravated the Climate change and its effects, which has led to the emergence of Urban Heat Islands (UHIs), heightened vulnerability to urban floods, and a decline in the Air Quality Index (AQI). These challenges are interconnected and pose significant threats to the sustainability and resilience of urban habitats, necessitating a comprehensive and integrated mitigation approach. This paper underscores the urgent need to address the above-mentioned issues and their associated impacts on urban environments. Recognising the interdependence of the three urban challenges, is crucial for developing effective mitigation approach. The integrated mitigation approach proposed in this research involves a combination of nature-based solutions focusing on urban planning, green infrastructure implementation, and sustainable development practices. The proposed mitigation approach includes strategies that caters to urban heat, mitigates urban and flash flooding and degrading air quality. Strengthening urban habitat risk resilience is imperative for the well-being of urban populations, ensuring a healthier, more sustainable future in the face of ongoing urbanization and climate change.

Keywords:
Urbanization, Urban Habitat, Resilience, Integrated approach.

Introduction

The defining trend of the twenty-first century, Urbanisation, has catapulted mankind into an era of unprecedented expansion, technical innovation, and interconnection. This increase in urban expansion, however, comes with a cost, measured in the rising sensitivity of urban environments to the effects of climate change. As our cities grow, so do the issues they confront, with urban heat, flooding, and poor air quality emerging as strong foes to the health and sustainability of urban settings. Climate change and global warming has further added to the challenges. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people.

The below figure clearly demonstrates the increasing temperatures, heat, and precipitation, which is likely to cause further catastrophes. The year 2023 witnessed a lot of such calamities around the world where events of extreme heat, flood and bad air quality affected the urban habitat.



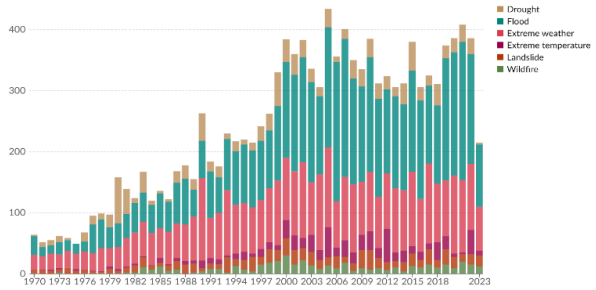
F1: Future predictions and impacts of climate change; (source: IPCC AR6 Synthesis report)

The figure below shows the annual reported number of disasters related to Heat, Flood, weather, and temperature. (this largely reflects the events reported and shall not be confused with the number of events)

Urban Heat: The Silent Scourge

Urban Heat Islands (UHIs) are rapidly becoming synonymous with urban settings, causing ambient temperatures to increase above those in surrounding rural regions. The increasing number of impermeable surfaces, energy-intensive infrastructure, and shrinking green spaces increases heat absorption, culminating in scorching conditions. Heat-related diseases are

becoming an alarming consequence of urban expansion, forcing city people to contend with not just high temperatures but also increased health hazards.



F2: Increment in natural disasters in last 50 years (last record - Sept 2023); (source: EM-DAT, CRED / UC Louvain (2023)

1.2 Urban Flood: The Inundation Menace

Natural drainage patterns are frequently disrupted by rapid urbanization, changing once-absorbent surfaces into impermeable obstacles. As a result, cities are more vulnerable to flooding, with heavy rains overflowing drainage systems and flooding urban areas. Low-lying, highly inhabited places bear the brunt of this difficulty, suffering property loss, infrastructure breakdown, and greater risk to human life. The complicated interplay between climate change-induced severe weather events and urbanization indicates the critical need of tackling the flooding crisis.

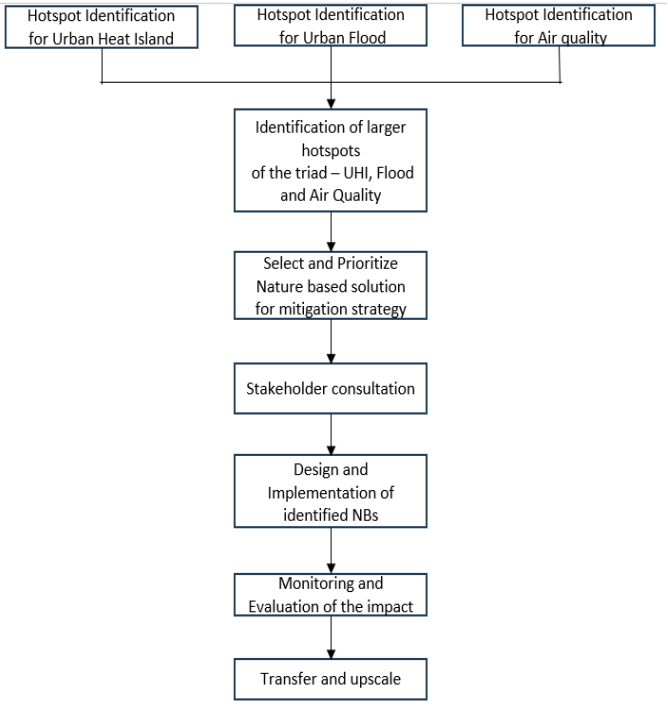
1.3 Degraded Air Quality: A looming Health crisis

The unseen threat of poor air quality hovers over urban landscapes, fueled by emissions from automobiles, industrial activity, and the encroachment of built environments. Pollutants such as particulate matter, nitrogen dioxide, and ozone are increasing in cities, posing serious threats to respiratory health and overall health. The consequences extend beyond physical health, impacting cognitive function and increasing existing socioeconomic inequities as vulnerable communities endure a disproportionate share of the burden of poor air quality.

The causes of these urban habitat threats are directly related to the rampant urbanization, which is marked by extensive infrastructure expansion, increasing energy use, and a disregard for ecological balance. Impermeable surfaces replace permeable ones, altering microclimates and reducing natural buffers. Furthermore, human activities such as industrial pollutants and automobile traffic contribute greatly to the worsening of air quality. As the correlation between urbanization and climate change gets stronger, the necessity for a proactive and integrated strategy to urban habitat risk resilience finds more prominence. This research investigates the complex difficulties faced by urban heat, flooding, and poor air quality, with the goal of identifying effective nature-based solutions that not only ameliorate these concerns but also strengthen urban habitat resilience in the face of an unpredictable and changing climate.

2.Materials and Methods

Addressing the multiple issues of urban heat, flooding, and poor air quality necessitates a comprehensive and coordinated strategy. This technique presents a systematic framework for effectively mitigating these urban habitat concerns by combining nature-based solutions and other sustainable measure.



F3: Framework for strengthening the Urban Habitat Risk resilience for the triad urban issues – Urban Heat, Urban Flood, and Urban Air Quality; (source: author)

Hotspot Identification

3.1**Urban Heat: this can be conducted using geospatial analysis as given below -**

1Land Cover Analysis:

1.1 Utilize satellite imagery and GIS mapping to analyze land cover types within the urban area.

1.2 Identify areas with high percentages of impervious surfaces (e.g., concrete, asphalt) contributing to Urban Heat Islands.

2 Surface Temperature Mapping:

2.1 Employ thermal infrared imagery from satellites or aerial surveys to map surface temperatures.

2.2 Identify and quantify Urban Heat Islands by comparing temperatures across different land cover categories.

3.Climate Data Integration:

3.1 Integrate historical climate data (temperature, precipitation) to identify areas experiencing higher-

than-average temperatures, contributing to Urban Heat

3.2**Urban Flood:**

1 Hydrological Modelling:

1.1 Utilize hydrological models to simulate surface runoff and flood risk based on topography, land cover, and precipitation data.

1.2 Identify areas prone to flooding by analyzing flow paths and potential inundation zones.

2 Drainage System Evaluation:

2.1 Assess the capacity and efficiency of existing drainage systems.

2.2 Identify areas with inadequate drainage infrastructure contributing to increased flood risk during extreme weather events.

3 Vulnerability Mapping:

3.3Combine topographical data with socio-economic data to create vulnerability maps.

3.2 Identify areas with a high concentration of vulnerable populations, emphasizing the social aspect of flood risk.

3.3 Air Quality:

1.Emission Source Mapping:

1.1 Map and categorize major emission sources, including industrial facilities, traffic corridors, and other potential contributors to air pollution.

1.2 Prioritize areas with dense emission sources as potential Air Quality hotspots.

2.Air Quality Monitoring Data:

2.1 Utilize historical air quality monitoring data from ground-based stations.

2.2 Identify areas with consistently high concentrations of air pollutants, such as PM2.5, NO2, and O3.

3.Wind Patterns and Dispersion Modelling:

3.1 Incorporate wind patterns and dispersion modelling to understand how pollutants disperse in the air.

3.2 Identify areas where stagnant air or specific wind patterns contribute to poor air quality.

Overlaying the identified hotspots for the three concerns - urban heat, flood, and air quality - will yield one or more overall hotspots for action. Engaging local government and the community in stakeholder consultations will help to gather anecdotal evidence and insights on perceived risks and vulnerabilities, as well as incorporate community knowledge to validate and refine hotspots and the prioritization of identified hotspots for intervention, which can be classified as high, medium, or low priority hotspots for intervention.

This comprehensive methodology ensures a data-driven and stakeholder-inclusive approach to hotspot identification and risk assessment. By integrating various data sources, modelling techniques, and community input, urban planners with government support, can develop targeted and effective strategies for mitigating the complex challenges posed by Urban Heat, Urban Flood, and degraded Air Quality in specific urban areas.

The integrated approach recognizes the interconnectedness of the triad (urban heat, flood, and air quality) and seeks to solve them collectively by leveraging synergies between nature-based initiatives and sustainable practices within a single intervention umbrella. This holistic method not only reduces immediate threats, but also helps to create more sustainable and livable urban settings.

Green Infrastructure Retrofitting:

1 Urban Green Spaces and Cool Pavements:

1.1 Creation of green spaces, such as urban parks and green corridors, to introduce vegetation and shade.

1.2 Implementation of cool pavement technologies or light-colored reflective surfaces to mitigate heat absorption.

2 Permeable Pavements and Rain Gardens:

2.1 Installation of permeable pavements to reduce surface runoff and enhance water absorption.

2.2 Integration of rain gardens to further enhance water retention and reduce flood risks.

3 Air-Filtering Vegetation and Green Roofs:

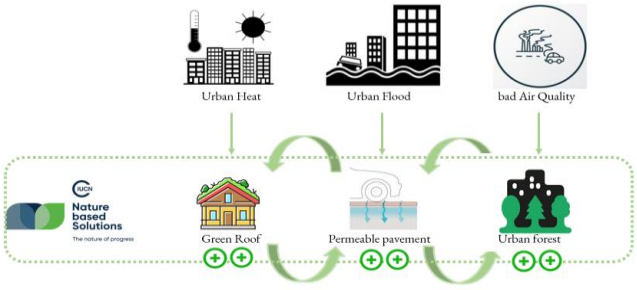
3.1 Strategic planting of trees and air-filtering vegetation to absorb pollutants and enhance air quality.

3.2 Implementation of green roofs to provide additional insulation, mitigate Urban Heat, and reduce stormwater runoff.

4 Sustainable Transportation and Pedestrian-Friendly Design:

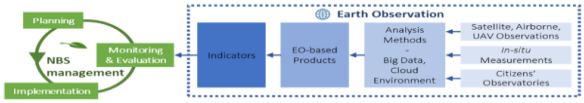
4.1 Promotion of sustainable transportation modes, such as cycling and walking, to reduce vehicular emissions.

4.2 Implementation of pedestrian-friendly infrastructure, such as wider sidewalks and dedicated bike lanes.



F4: Combination of Nature-based solutions and sustainable practices that mitigate Urban heat, flood, and air quality issues, (source: EPA, author)

Monitoring and evaluation play a pivotal role in the success and upscaling of nature-based solutions aimed at mitigating urban heat, flood, and air quality issues. The need for a robust monitoring and evaluation framework arises from the dynamic nature of urban environments and the complexity of interventions.



F5: Monitoring and Evaluation framework by means of Earth Observation

Regular monitoring allows for real-time assessment of the implemented NSs, enabling stakeholders to gauge their effectiveness in addressing specific challenges. Following ways are proposed for monitoring the impact of NBS –

1. **Real-Time Sensor Networks:**
a. Deploy real-time sensor networks to continuously monitor key parameters such as temperature variations, air quality indices, and precipitation levels.
b. Install sensors strategically in hotspot areas and across the urban landscape to capture comprehensive data.
2. **Satellite Imagery and Remote Sensing:**
a. Utilize satellite imagery and remote sensing technologies to monitor changes in land cover, vegetation health, and temperature patterns.
b. Periodically analyze satellite data to assess the impact of nature-based solutions on the overall urban environment.
3. **Community-Based Monitoring:**
a. Engage local communities in monitoring efforts through citizen science initiatives.
b. Encourage residents to report observations related to temperature, flooding, and air quality, creating a valuable participatory data collection process.
4. **Air Quality Monitoring Stations:**
a. Establish air quality monitoring stations in key locations to measure concentrations of pollutants, including particulate matter, nitrogen dioxide, and ozone.
b. Analyze data from these stations to assess the effectiveness of nature-based solutions in improving air quality.
5. **Green Infrastructure Performance Assessments:**
a. Conduct regular assessments of green infrastructure elements, such as green roofs, urban parks, and permeable pavements.
b. Evaluate the health and functionality of vegetation to ensure it continues to provide the intended benefits.
6. **Hydrological Models for Flood Monitoring:**
a. Employ hydrological models to simulate surface runoff, drainage patterns, and flood risk.
b. Utilize data from monitoring stations and remote sensing to validate and refine the models over time.
7. **Temperature Mapping:**
a. Use thermal infrared imagery to create temperature maps, helping visualize Urban Heat Island effects.
b. Compare temperature maps over different time periods to assess the impact of nature-based solutions on local microclimates.
8. **Health and Well-being Indicators:**
a. Monitor health indicators within the community to assess the impact of improved air quality and reduced urban heat on residents' well-being.
b. Track hospital admissions related to heat-related illnesses and respiratory conditions to gauge the effectiveness of interventions.
9. **Community engagement and ownership**

The above information will cater to analyses and assessments for temperature reduction, flood risk reduction, air quality improvement, cost-benefit, and social performances of the implemented NBs.

F6: Reporting impact from the interventions to all stakeholders, source: author

This data-driven approach not only ensures accountability but also facilitates evidence-based decision-making for future projects. Figure 6 showcases the logical steps for data collection, monitoring, evaluation and sharing the impact with the concerned stakeholders – community, municipality, and other local authorities.

The insights gained from monitoring and evaluation become essential for upscaling projects, as they can provide a solid foundation of knowledge and best practices that can be transferred to different urban settings, ultimately contributing to the broader goal of creating sustainable, resilient, and nature-friendly cities. The results can be used to set the base for policy advocacy and additions/ revisions in master plans for the cities.

Results drawn from case examples

Nature based Solutions (NBs) are gaining popularity in recent years in tackling environmental issues especially climate change and air pollution due to its potential co-benefits. NbS are sustainable options to mitigate the harmful effects of climate change and pollution, improving the health and well-being of city residents at the same time benefiting biodiversity in the most resource-efficient way. The following case examples provides a proof of concept for adopting Nature based Solutions as a mitigation strategy for enhancing Urban Habitat

Risk Resilience –

The case example of the city of Xiangtan in Hunan province, China under Asian Development Bank (ADB) project -

Issues of flooding in some parts of city Temperature extremes

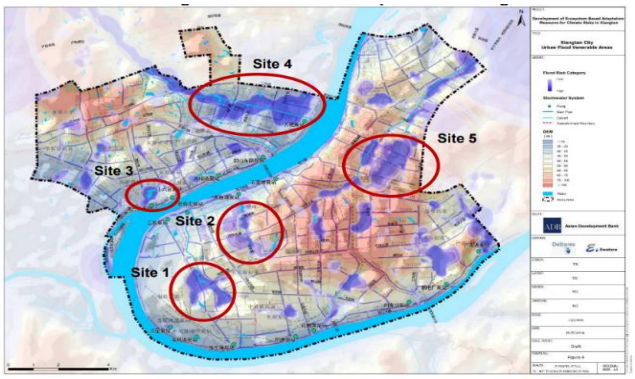
The city used the climate resilient city tool to mitigate the issues. The solutions like **permeable pavement, rain garden, bio-retention cell, street trees, green roof** with drainage delay, etc. were used for the mitigation. Following sites were identified for intervention using the hydrogeological, LULC, Temperature data analyses –

An observation on Heat reduction by 0.37 C, increment in water storage capacity of 6447 cubic meter, a groundwater recharge of 117mm annually, was made using the solutions like green roofs, Urban wetlands, Urban forests, Infiltration boxes, bioswales. These results were further shared with the local stakeholders - Xiangtan Municipal Commission of Development and Reform and others, to incorporate the interventions for the policy advocacy and incorporation in the 2030 master plan.

4.1 City of Milan, Italy: The city's strategic environmental plan recognises 'green infrastructure' as the most effective means to meet environmental goals, stimulate social development, and increase social welfare. The plan describes the financing channels and offers guidance to the various municipalities for ecosystem maintenance and creation. The city has implemented two main NBS strategies: vertical gardens and green urban areas. According to studies, urban parks have a significant cooling impact on areas near urban green spaces. It also demonstrated that the vertical garden in two buildings might reduce particle concentration.[1]

4.2 Singapore government had introduced the Landscaping for Urban Spaces and High-Rises (LUSH) Programme in 2009. The program aimed to further strengthen efforts in greening the city and to encourage more pervasive greenery within Singapore's high-rise urban environment and to make Singapore a green city and has been widely acknowledged as one of the most innovative Urban Greenery Project.[2]

Location (Köppen classification, Kottek et al., 2006)	Month	Green site & comparator	Features of green site	Size
Nagoya, Japan (Cfa)	March and August	One park compared with urban areas	forest, lawn, ponds, fields, spaces containing monuments and badlands	147 ha
London, UK (Cfb)	August to December (nights)	One large park	Water body, mixed grass land and treed landscapes, and formal avenues and gardens	111 ha
Beijing, China (Dwa)	August 21	One park, Comparison of entire park with uncovered sites in the park	Grass, 10 & 20 m trees, hardened ground, water body and buildings	102 ha
Shanghai, China (Cfa)	November to January	One park, The squares in the park were compared	Surrounded by trees and benches	21.42 ha



LUSH (Landscaping for Urban Spaces and High-Rises) programme by Urban Redevelopment Authority (URA)

A significant amount of greenery within city developments today is a result of URA guidelines, which required developers to provide greenery in various forms. For example, developers had to provide tree planting verges along the public roads.

LUSH 2.0 launched in 2014, further aimed at covering more development types ranging from residential developments to office, retail and even hotel developments having vertical green spaces. The geographical coverage of LUSH 2.0 spread across most of Singapore. URA Singapore have added more than 40 hectares of green spaces within Singapore's urban environment. They have incorporated greenery into

[1] OECD (2023), Developing an Integrated Approach to Green Infrastructure in Italy, OECD Public Governance Reviews, OECD Publishing, Paris, https://doi.org/10.1787/d84bb8e4-en.

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their developments in the form of sky terraces, rooftop gardens and vertical green walls. The programme facilitated more pervasive and accessible urban greenery with the intent to enhance people's overall well-being, living and working environment.

4.3 Green spaces/ parks acting as mitigation solution for UHI and AQI. A study conducted on multiple urban parks across different climatic zones, analysed the cooling effects of parks with different sizes (0.2–0.36 ha) and different vegetation quality and diversity. It was found that parks with dense vegetation cover have the greatest effectiveness in terms of cooling and thermal comfort. The greatest cooling effect was observed in parks of Tel Aviv during summer, when the parks managed to reduce the temperature by up to 3.8 °C, resulting in a PET of 18 °C (PET = Physiological Equivalent Temperature, which is an indicator of human comfort under temperature variations). [3] The table below provides an understanding on the bases for the study and how the cooling effect was monitored[4].

4.4 Stuttgart, Germany: Combating the heat island effect and poor air quality with ventilation corridors and green-blue infrastructure - air ventilation corridors. Several planning and zoning regulations were recommended to preserve and increase open space in densely built-up areas. It resulted in preservation and enhancement of air exchange and cool air flows in the city.

Discussion and Conclusion

With steadily growing impacts of climate change, cities are increasingly struggling with the challenges of UHI, urban floods and declining AQI. As shown in the case studies, the nature-based solutions are responding positively to the various challenges – individually as well as mutually (in some case example – Urban heat and degraded AQI). The adoption of nature-based solutions emerges as a transformative strategy for cities seeking to simultaneously address urban heat, flood, and air quality issues. This research advocates on

adopting the integrated approach of nature-based solutions and other sustainable practices for mitigating the three challenges together with an intent to implement one kind of interventions and have a positive impact on the two or more challenges. It not only showcases the adaptability of nature to solve complex urban challenges but also aligns with the broader global agenda of creating sustainable and resilient cities.

The multifunctional benefits of nature-based solutions extend beyond mere mitigation; they offer a blueprint for building urban landscapes that harmonize with the natural environment. The success stories of urban areas that have embraced nature-based solutions underscore the potential for these interventions to enhance urban resilience, promote ecological balance, and elevate the overall quality of urban life.

While observing the positive outcomes achieved in the adoption of nature-based solutions, it is critical to recognize that their implementation necessitates collaboration across varied sectors. A successful NBS strategy must include effective urban planning, community involvement, and policy integration. Continuous monitoring, assessment, and adaptive management are required to fine-tune techniques, learn from experiences, and guarantee the efficacy of nature-based treatments is maintained.

In conclusion, incorporating nature-based solutions is a critical step towards constructing cities that not only resist the challenges of climate change, but also thrive as sustainable and dynamic urban ecosystems. As the world pursues urban resilience collectively, the adoption of nature-based solutions emerges as a lighthouse, directing cities towards a future where the built environment and the natural world coexist in harmony, assuring a healthier, more sustainable, and resilient urban future.

Purpose	Methods/ Instruments	Conclusion
Clarifying the range of the cool-island effect of a green area on an urban area, as well as the relationship between vegetation and air temperatures	• with temperature and humidity sensors 24 fixed measurement sites	The range of the cooling effect as well as the relationship between the vegetation cover and air temperature throughout the year
Providing empirical evidence for the extent of cooling of London's UHI with one large greenspace	• Mobile measurement • A developed correlation	Using meteorological stations close to urban greenspace can lead to underestimation of urban heat island intensity due to the cooling effect of the greenspace.
Assessing the impacts of these parameters on thermal comfort improving effect of UGSs.	• PET Index • Simulation by ENVI-met and Rayman • Regression method Stationary	The most significant influencing factor on the moderation of thermal comfort is the higher trees, while hardened ground exhibits a negative impact
Examining the relationship between outdoor micro-meteorological conditions and people's thermal comfort perception	• PET index • Mobile micro meteorological stations	Visitors' thermal sensations and space use were more significantly affected by the micro- meteorological factors in winter compared with autumn

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Author Profile

Rajlakshmi Dubey holds both B.Arch. and M.Arch. degrees from Hitkarini College of Architecture and Town Planning, Jabalpur, and Kamala Raheja Vidyanidhi Institute for Architecture and Environmental Studies, Mumbai, obtained in 2016 and 2020, respectively. From 2020 to 2023, she dedicated her efforts to remote areas in Bundelkhand, a water-deprived region in Madhya Pradesh, specifically working in the villages of Chhatarpur, Nowgaon, and Jhansi. Her focus was on ground water management and livelihood enhancement, collaborating with the NGO Haritika.

In collaboration with the Madhya Pradesh Tourism Board (MPTB), during her tenure at Haritika, Rajlakshmi played a pivotal role in improving the livelihoods of villagers. She achieved this by facilitating the development and promotion of eco-tourism, implementing successful interventions of rural homestays in Ladpura Khas village near Orchha. Her work extended beyond economic aspects, also emphasizing the cultural sustainability of the region.

Transitioning to the Aga Khan Agency for Habitat India, Rajlakshmi contributed to broader environmental initiatives. Her involvement spanned projects like the Integrated Rural Habitat Development Programme (IRHDP) and Urban Heat Island (UHI) mitigation. These initiatives addressed the impacts of climate change, focusing on both mitigation and adaptation strategies. She further continues her research for Climate change mitigation and adaptation, their effects in vulnerable populations in urban settings and sustainable solutions and practices that could help reduce the impact on the vulnerable populations.

Demonstrating Solid Waste Management and Zero Waste Strategies for Residential Neighborhoods - A Case of DSK Vishwa, Pune.

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Abstract:
Nestled in green cover and situated between one of Pune's urban forests, DSK Vishwa, is a residential locality situated in Dhayari Pune. Known to be a great neighborhood for residential & commercial facilities, DSK Vishwa is well connected with good quality roads, a safe environment with schools, markets, parlors & shopping centers all situated in and around the locality. At the inception of the project, DSK Vishwa was conceived not as a cluster of houses, but as a world that had a beautiful blend of nature and city conveniences.
During its early years and after the proposed expansion in the year 2016, DSK Vishwa was projected as a neighborhood with all the amenities and conveniences developed go hand-in-hand with comfort, convenience and nature. An Environment Management Plan was proposed to reduce the impacts on the air environment, land environment, water environment, vegetation & fauna during the construction phase and operation phase. An EIA report was also made with all mitigation measures to be undertaken to reduce environmental damage during the construction, operation and the entire life cycle of the project for which a sewage management , stormwater management , energy conservation and management plan etc. was laid down for the project. A Solid Waste Management plan for segregation of non-biodegradable and biodegradable garbage on site, treatment and recycling with authorized recyclers was also proposed during the expansion.
However, over the period of time & in the current situation, improper disposal and poor management of solid waste in the neighborhood is observed due to absence of long-term waste management strategies, and weak coordination between authorities & residents of the neighborhood.
Inappropriate & illegal dumping of domestic residential & commercial waste , construction & demolition waste etc. in the open areas, gardens ,vacant plots, road dividers and on the road side is leading to direct and adverse impacts on environment and health. The research paper therefore intends to provide practical and step-by-step guidance for efficient Waste Management & Net Zero Waste Strategies to the housing societies, commercial setups & neighborhood authorities to avoid environmental damage. The research paper also provides the residents and decision-makers a set of tools & long-term solutions for achieving net zero waste by means of reducing, reusing, and recovering waste to convert them to valuable resources for environmentally conscious neighborhoods.

Keywords:
Waste Management, Zero Waste Management, Waste Recovery, Sustainable Solutions, Waste Recycling.

1. Introduction

Successful waste management solutions for residential neighborhoods have never been more crucial. The volume of waste generated increases, as the population in urban areas grows. It is essential for residential neighborhoods to adopt efficient waste management solutions to maintain clean and environmentally responsible communities. Residential neighborhoods of all scales generate a considerable amount of waste daily. Inefficient waste management not only leads to unpleasant surroundings but also poses health and environmental hazards. Effective waste management in residential neighborhoods plays a most important role as the residential sector acts as bulk waste generators in most of the cities. An average person generates about 0.4 to 0.6 kilograms per day that exceeds 1.2 kilograms during cultural events and festivals in an Indian context. Having a suitable waste management system for residential neighborhoods is like taking one enormous step towards a zero waste, environmentally conscious community.

2. The Case of DSK Vishwa Pune

Nestled in green cover and situated between one of Pune's urban forests, DSK Vishwa is a residential locality situated in Dhayari Pune. Known to be a great neighborhood for residential & commercial facilities, DSK Vishwa is well connected with good quality roads, and a safe environment with schools, markets, parlors & shopping centers all situated in and around the locality. At the inception of the project, DSK Vishwa was conceived not as a cluster of houses, but as a world that had a beautiful blend of nature and city conveniences.

During its early years and after the proposed expansion in the year 2016, DSK Vishwa was projected as a neighborhood with all the amenities and conveniences developed go hand-in-hand with comfort, convenience, and nature. An Environment Management Plan was proposed to reduce the impacts on the air environment, land environment, water environment, vegetation & fauna during the construction phase and operation phase. An EIA report was also made with all mitigation measures to be undertaken to reduce environmental damage during the construction, operation, and entire life cycle of the project for which sewage management, stormwater management, energy conservation and management plan, etc. was laid down for the project. A Solid Waste Management Plan for the segregation of non-biodegradable and biodegradable garbage on-site, treatment, and recycling with authorized recyclers was also proposed during the expansion.

3. Spatial Distribution: Types of Built and Open Spaces in DSK Vishwa, Pune

Location: DSK Vishwa, Dhayari, Pune
Lat. & Longitude: 18.26 N , 73.47 E , MSL: 667 meters

F1: (*Source - Google earth.com) *North Upright

Area:
Existing Plot Area: 3,73,754.00 Sq m.
Proposed Expansion Plot Area: 39,591.00 Sq m.
Total Plot Area After Expansion: 4,13,345.00 Sq m.
Existing Built Up Area: 4,61,458.32 Sq m.
Expansion Built Up Area (Residential + Commercial + Club House):
(70150.77 + 30961.12 + 4565.84) = 105677.7 Sq m.
Total Built Up Area After Expansion: 6,04,188.3 Sq m.

Plot Details :
Gut No.83/B/2,85,86/1,87,88,89,90,92/1,99,100,101.102,103104,105 & 106 At Kirkitwadi & S.No. 122/2,126/1(P),126/2/1(P),126/3To10(P) ,126/11/1(P) ,126/11/2,126/12 To 16, 126/2/3 & 4, 125/01To04, 08/58(P), 125/6/1, 124/3, 14/4 of Dhayari, S.No.124/2, 124/6, 124/7/1, 124/7/2, 124/8, 124/15, 186,187,188 Kirkitwadi, Dhayari, Pune, Maharashtra.

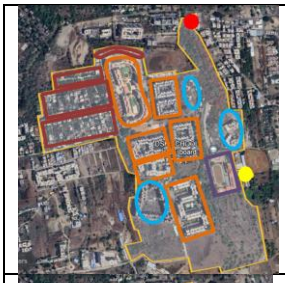
F2: (Source- M/s DSK Developers Ltd., EIA Document) *North Upright

Types of Spaces:
Residential:
Residential Apartments, Gated residential colonies, Row Houses, Bungalow Plots.

Commercial & Shopping Spaces:
Commercial Shops, Grocery Shops, Eateries, Restaurants, Roadside food stalls, Weekly vegetable market, roadside vegetable vendors,

Ancillary Spaces: Sports Ground, Temples, School, Clinics, Diagnostic centers, Open Spaces, Joggers Park, playground, Hospital (not occupied), Open/vacant plots

Services:
Bank and ATM facilities, Bus Stand, Open parking, Transformers, existing sewage treatment plant, Surface water tank, existing Garbage segregation spaces (inadequate and not in working conditions)



Green Spaces (Urban Forest), Joggers Park and Open ground for Outdoor Activities

Main Roads, Internal Streets and vacant plots

F3: Location of Garbage Unit, Water Storage and Waste Water Treatment unit (*Source - Google earth.com) *North Upright

3.1 Existing Scenario of Solid Waste for the Case of DSK Vishwa, Pune

Since the last few years, inappropriate & illegal dumping of domestic residential & commercial waste , construction & demolition waste etc. in the open areas, gardens ,vacant plots, road dividers and on the road side is observed. This is leading to direct and adverse impacts on environment and health. Over a period of time & in the current situation, improper disposal and poor management of solid waste in the neighborhood is observed due to absence of long-term waste

management strategies, and weak coordination between authorities and residents of the neighborhood.

3.2 Observation of Solid Waste Scenario for the Case of DSK Vishwa, Pune

- Verbal Survey with residents and shop owners indicated that residential apartments, gated societies and bungalows say to have a domestic waste collection system which is further addressed by the local municipal authorities.
- Existing allocated Garbage Segregation and storage unit in the neighborhood is inadequate and not in use.
- Existing Door to door collection of residential apartments, gated societies and bungalows but no onsite segregation and disposal systems available.
- Inappropriate dumping of domestic residential waste in the open areas and vacant plots in the neighborhood by the apartments as well as residential societies in the vicinity.
- Illegal dumping of construction & demolition waste opens areas, vacant plots and roadside spaces of the renovation projects in the neighborhood and as well as from the vicinity areas.
- Inappropriate disposal of commercial waste from eateries, roadside food stalls and a few commercial shops on the road sides, road dividers and open areas leading to environmental issues and nuisance creation by stray animals.
- The neighborhood has a lot of vegetation and green cover throughout the year leading to generations of large amounts of leaves, tree limbs, branches, stumps, grass clipping and other waste plant material. There are no existing collection and disposal systems of vegetation waste generated which litters the roadside areas causing inconvenience to the pedestrians.
- A number of abandoned vehicles in the neighborhood are not only an eyesore, but take up valuable parking spaces.

Inappropriate dumping of domestic residential waste in the open areas and vacant plots in the neighborhood

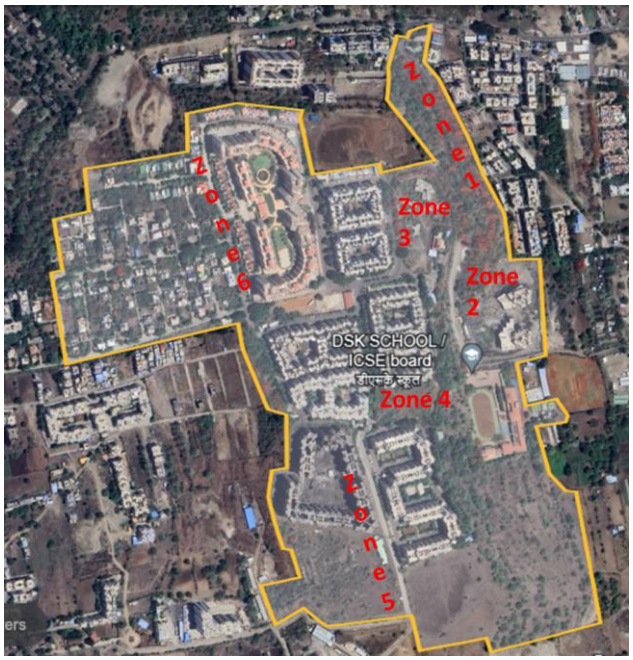
Inappropriate dumping of domestic residential waste on the road sides and road dividers

Vegetation waste generated litter on the roadside areas causing inconvenience to the pedestrians.

Abandoned vehicles in the neighborhood taking up valuable parking spaces.

Illegal dumping of construction & demolition waste opens areas, vacant plots and roadside spaces

4 Existing Waste dumping locations for the Case of DSK Vishwa, Pune



F4: Zone 1 to Zone 6 – DSK Vishwa, Pune

Zone 1 - DSK Vishwa Main Road: Waste Dumping in open areas, road sides and road dividers

Zone 2 - DSK Vishwa Main Road: Waste Dumping on roadsides near DSK School Road

Zone 3 - DSK Vishwa Main Road: Waste Dumping in vacant and abandoned plots

Zone 4 - DSK Vishwa Internal Roads: Waste Dumping in vacant and abandoned plots

Zone 5 - DSK Vishwa Internal Roads: Waste Dumping in vacant and abandoned plots

Zone 6 - DSK Vishwa Internal Roads: Waste Dumping on road sides

4.1 Solid Waste Classification for the Case of DSK Vishwa, Pune

Solid waste in residential neighborhoods can be classified into two types: biodegradable and non-biodegradable. Biodegradable waste is that which can be decomposed by biological processes, for example, vegetable peel, food, farm waste, and so on. Organic waste is biodegradable and can be recycled; and Non-biodegradable waste cannot be broken down by biological processes, for example, paper, glass, metal, and so on. Non- biodegradable waste can be further

classified into two types: recyclable and non-recyclable. Recyclable waste is that waste which has economic value that can be recovered, for example, metal, paper, glass, plastic bottle, and Non-recyclable waste is that waste which does not have economic value of recovery, for example, tetra packs, thermocol, and so on. A typical Residential/ Household Waste can be classified into 3 categories: Dry Waste, Wet Waste & Hazardous Waste.

"Dry waste" means waste other than bio-degradable waste and inert sweepings.
"Wet Waste or organic waste" is generally biodegradable in nature, and mostly comes from the kitchen.
"Household Hazardous Waste" (HHW) consists of unwanted household products that are labeled as flammable, toxic, corrosive, or reactive.

Contents of Waste Generated from the Residential Apartments, Gated Societies and Bungalows:

1) Organic Waste

- Wet waste – Food leftovers, fruit/vegetable peels, waste tea powder, landscape and pruning waste, other green waste, processed food, raw food materials, meat and bones, food-soiled paper, eggshells, leaf plates etc.
- Dry waste – Newspapers, magazines, paper bags, paper packaging materials, ribbons, strings, leaflets, notebooks, wood, furniture etc.

2) Non-organic Recyclable waste (solid rubbish)

- Plastic – Plastic bags, containers, jars, bottles, covers, caps, milk pouches, food packets, soda bottles, wrappers etc.
- Metals– Utensils, batteries, pipes, nails, tools, aluminum foils, metal scraps, tetra packs, wires etc.
- Glass– Bottles, plates, cups, shards, mirrors, ceramics etc.

3) Hazardous waste

- Insect sprays, syringes, diapers, sanitary napkins, cleaning chemicals, bleach containers, corrosives, flammable liquids, solvent-based paint, car batteries, e-waste, bio-medical waste etc.

4) Inert Waste

- Sand, concrete, clay, subsoil, rubble etc.

Most household waste in residential neighborhoods is organic, with little inorganic material, and is non-toxic.

Based on its physical properties or contents of waste can be classified as:

Biodegradable	55 – 75%
Recyclables	20 – 30%
Inert Material	5 – 10%

Contents of Waste Generated from the shops, eateries, hotels, vegetable market, school etc.
Including (but not limited to) paper, cardboard, cans, retail packaging, food wrappers, leftover food, glasses, metals, ashes, etc.

Contents of Waste Generated from the Clinics, diagnostics centers etc.
Biomedical waste - Sharps & Waste like needles, scalpels, broken glass and razors. Pharmaceutical Waste & Unused and expired drugs or medicines, like creams, pills, antibiotics.

Contents of Waste Generated from open areas, vegetation, streets, alleys, parks, vacant lots etc.
Leaves, tree limbs, branches, stumps, grass clipping and other waste plant material

Abandoned vehicles - This category includes automobiles, and cars that are abandoned on internal streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable.

Contents of Construction and demolition wastes:
These are wastes generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. They consist mainly of earth, stones, and concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.

Contents of Special Waste / E waste generated from residences, shops, eatery cash counters, school, etc.
Batteries, computer parts, wires, electrical, watches, cell phones, bulbs, tube lights, CFL etc.

Solid Waste Generation for the Case of DSK Vishwa, Pune
As per the EIA, Form 1A, Solid Waste Generation During Operation Phase was projected as :

Solid Waste Generation	Total solid waste (Kg)	60% wet solid waste (Kg)	40% dry solid waste (Kg)
Existing Project	11411	7975	3436
Residential Proposed expansion	1872.5	1123.5	749
Commercial	1031	618.75	412.50
Total	14314.5	9717.25	4597.5

Considerations for solid waste generation as per norms:

For Residential:

60 % biodegradable and 40 % non-biodegradable out of total 0.5 Kg/person/day

For Commercial:

Employees & Service Staff: 60% non-biodegradable and 40% biodegradable out of total 0.15 Kg/person /day

The total quantities of solid waste that will be generated in the project will be 14314.5 kg/day out of which 4597.5kg/day will be non-biodegradable and 9717.25kg/day will be biodegradable.

Segregation of non-biodegradable and biodegradable garbage on site.

Status of Solid Waste Generation for the existing condition: 0.5 Kg/person/day

Residential Apartments & Gated Societies
Name of Apartment: DSK Pawan No of Buildings: 6 Floors per building:7 No. of Flats per building:42 No. of tenements per flat:5 Average no. of Tenements:1260 Total solid waste (kg):630 60% wet solid waste (Kg):378 40% dry solid waste (Kg):250
Name of Apartment: DSK Varun No of Buildings:6 Floors per building:7 No. of Flats per building:42 No. of tenements per flat:5 Average no. of Tenements:1260 Total solid waste (kg):630 60% wet solid waste (Kg):378 40% dry solid waste (Kg):250
Name of Apartment: DSK Vasudha No of Buildings: 8 Floors per building:7 No. of Flats per building:49 No. of tenements per flat:5 Average no. of Tenements:1960 Total solid waste (kg):980 60% wet solid waste (Kg):588 40% dry solid waste (Kg):392
Name of Apartment: DSK Bhaskara No of Buildings: 8 Floors per building:7 No. of Flats per building:49 No. of tenements per flat:5 Average no. of Tenements:1960 Total solid waste (kg):980 60% wet solid waste (Kg):588 40% dry solid waste (Kg):392
Name of Apartment: DSK Rohini No of Buildings: 15 Floors per building:7 No. of Flats per building: 49 No. of tenements per flat:5 Average no. of Tenements: 3675 Total solid waste (kg): 1838 60% wet solid waste (Kg): 1103 40% dry solid waste (Kg): 735
Name of Apartment: DSK Chandrama No of Buildings: 12 Floors per building:7 No. of Flats per building:28 No. of tenements per flat:5 Average no. of Tenements:1680 Total solid waste (kg): 840 60% wet solid waste (Kg): 408 40% dry solid waste (Kg): 272
Name of Apartment: DSK Saptasur No of Buildings: 8 Floors per building: 7 No. of Flats per building:28 No. of tenements per flat:5 Average no. of Tenements:1120 Total solid waste (kg): 560 60% wet solid waste (Kg): 336 40% dry solid waste (Kg): 224
Name of Apartment: DSK Meghmalhar No of Buildings: 23 Floors per building:7 & 11 No. of Flats per building:36 No. of tenements per flat:5 Average no. of Tenements:4140 Total solid waste (kg): 2070 60% wet solid waste (Kg): 1242 40% dry solid waste (Kg): 828

Total Solid Waste Generated	8528 kgs/day	5117 kgs/day	3411 kgs/day
Residential Bungalow Plots			
Name of Bungalow societies: DSK Sayantara 1 & 2 & row houses No of Buildings: 100 Floors per building: G+1 No. of tenements per bungalow :6 Average no. of Tenements:600 Total solid waste (kg): 300 60% wet solid waste (Kg): 180 40% dry solid waste (Kg): 120			
Total Solid Waste Generated from residential sector	8828 kgs/day	5297 kgs/day	3531 kgs/day

Solid Waste Generated from shops, eateries, hotels	200 -400 kgs/day

, vegetable market etc per week approx. 1.5 kg per day	
Solid Waste / Biomass Generated from open areas, vegetation, streets, alleys, parks etc in kg dry weight per m 2	Data not available
Construction and Demolition Waste	As per project. Not to be included in Domestic & Commercial waste as per C&D Waste Management Rules.

Solid Waste Generation	Total solid waste (Kg) per day	60% wet solid waste (Kg)per day	40% dry solid waste (Kg)per day
As mentioned in Environment Management Plan			
Residential	13283.5	9098.5	4185
Commercial	1031.27	618.8	412.5
Total Waste Generated	14314	9717	4598
Status of Solid Waste Generation for the existing condition			
Residential	8828	5297	3531
Commercial	200 - 400	120 - 240	80- 160
Total Waste Generated	9228	5537	3371
Three residential projects have been stalled since early 2019 which had led to a gap in the quantity of waste generated as proposed in the environment management plan and existing status of solid waste generation.			

4. Issues and Challenges of Solid Waste Management for the Case of DSK Vishwa, Pune

The prevalent setback with the solid waste scenario for the existing case is the insufficient waste collection infrastructure, lack of efficient sorting and recycling systems. This had contributed to the growing case of inappropriate dumping and disposal of residential, commercial and construction & demolition waste in and around premises leading to waste of resources, and environmental pollution. Ineffective disposal -causes air pollution, water and soil contamination. Open and unsanitary disposal contribute to soil contamination and unsightly conditions.

A. Limited or No segregation at source- Incorrect and Inadequate Segregation Techniques

- Lack of awareness of waste management rules and/or unwillingness about segregation for both residential and commercial waste.
- No strict rules that penalize non-segregation.
- Availability of waste collectors who don't refuse mixed waste for both residential and commercial waste.
- Lack of Civic Responsibility - Habit of open dumping by shop owners, eateries, vegetable vendors, roadside food vendors.

B. Incorrect/inadequate segregation techniques-

- Segregation without minimizing the amount of waste generated.
- Waste passes through multiple hands before final disposal.
- Dry and wet waste is separated in two garbage bags, doubling the volume of plastic waste.
- Incorrect disposal of e-waste.
- Incorrect disposal of Construction and demolition waste.

C. No adoption of in-house composting-

- Operational inefficiencies of services
- Lack of interest and low enthusiasm
- Budgetary constraints

D. Improper Waste Management

E. Lack of monitoring -garbage collection, Sorting recyclable materials, e-waste collection.

F. Inconsistent Collection

G. Municipal authorities do not consider all areas in the neighborhood for waste management leading to ineffective waste management and open dumping and roadside littering causing environmental problems.

Littering and Illegal Dumping

- Lack of holistic waste management plan - realistic and promising approach to efficient waste management.
- Lack of management plan and collection systems for waste generated for open areas, vegetation, streets, alleys, parks etc
- Inadequacy of garbage collection infrastructure, inefficient sorting of recyclable materials, limited recycling rates, and improper disposal practices.

5. Strategic and Scientific Waste Management Plan for the Case of DSK Vishwa, Pune

Strategic & Scientific Waste Management Plan:

- Scientific studies and planning - identifying the type of waste, the costs involved, and the best locations for disposal facilities.
- Use of innovative technologies for waste treatment and recycling.

- Developing an appropriate recycling infrastructure.
- Improve waste collection - Combining informal and formal waste collection sectors - decentralized waste management, where residents/ residential societies take care of waste treatment, and promoting recycling by implementing supportive policies and regulations.
- Treating organic waste
- Waste-to-energy methods
- Reviving existing dumps
- Strictly implementing waste management rules - "Polluter Pays Principle," is crucial to penalize those who don't comply.
- Public awareness towards waste management by making it a priority, not an afterthought.
- Public awareness- Health Issues, Environmental Issues, Economic Impacts.
- Awareness - Steps taken by the Government regarding Waste Management.

Awareness & strict implementation - Solid Waste Management Rules, e-Waste Management Rules, Plastic Waste Management Rules etc
Awareness - Government Initiatives:
(a) Swachha Bharat Mission
(b) Swaccha Survekshan
(c) Swachhata Hi Sewa Campaign
(d) Compost Banao, Compost Apnao Campaign
(e) Promotion of Waste to Energy

6. **Zero Waste Strategies for the Case of DSK Vishwa, Pune**

Recommendations for Decentralized Residential Waste / Household Waste:

- Segregate waste at building level and site level.
- Encourage reuse or recycling of materials to avoid associated environmental impacts.

At Site Level:

- Allocate centralized facility to store, segregate and handover collected waste to the identified recycle vendors.
- List & inventory of segregated waste streams.
- Divert other waste such as E-waste, medical waste, and hazardous waste to authorized recyclers and vendors.
- Allocate facility of Treatment of organic - biodegradable waste for conversion to manure or waste to energy.

At Building Level:

- Provide color coded bins to collect bio-degradable & non-biodegradable waste at all the floors and common areas of the building,
- **Blue bin** - Paper Recycling- Office paper, clean cardboard, newspaper, milk & juice cartons, disposable coffee cup-lids only
- **Green bin** - Organic Recycling- Food, pruning's, fruit & vegetables, plate scrapings including meat, fish & leftovers, flowers,
- **Red bin** - Hazardous waste- Sanitary napkins, diapers, used syringes blades, bandages, expired medicines.
- **Yellow bin**- Mixed recycling- Glass bottles, aluminum cans
- **Grey bin-** Soft plastic recycling - Bread bags, pasta & rice bags, cling wrap, plastic bags, biscuit packets, frozen food bags, bubble wraps.
- **Black bin**- E-waste-CFL, tube light, printer cartridges, batteries etc.

Biodegradable Treatment Systems	**Non biodegradable Waste Treatment Systems**
Decentralized Composting - By Product Manure - can be used as soil conditioner **Small Scale Anaerobic Digestion (Bio-Gas):** Biogas Generation-Biogas as fuel and the residue is used as manure, **Liquid Manure** **Vermi-Composting** **Organic Waste Converter** **Green Waste** **Re-processor machines** **Mechanical Composting**	**Use 3R's systems** - Reduce, Reuse and Recycle Reduce- Encourage practices that reduce waste generation during operation. Reuse - **contribute** by investing in reusable products. Recycle- generation of beneficial and marketable material.

Recommendations for Centralized Residential Waste / Household Waste: Waste to Energy

- Bio methanation Plant - by-products in the form of biogas and bio-manure.
- Bio CNG plant- valuable bio fuel and organic manure.
- Thermal processing for Biofuel and/or Biogas for energy generation can be done for street lighting and security lighting of parks and open areas**.**
-

Recommendations for Commercial Waste - shops, eateries, hotels, vegetable market, school etc.

- Track and reduce the waste generated.
- Adopt waste sorting systems - Ensure segregation of biodegradable and non-biodegradable waste.

Biodegradable Waste- Waste stream can be channelized to central organic waste treatment units.

Non-Biodegradable Waste-

- Implement strategies and measures for reducing waste generation.
- Implement strategies for Plastic Waste Management - ensure proper storage, collection, and disposal of plastic waste

- Recycling of non-bio-degradable waste through responsible handling and handing over of the same to the respective recyclers.

- **Recommendations for Waste Generated from open areas, vegetation, streets, alleys, parks, vacant lots etc.**
- Pyrolysis of garden waste.
- Composting.
- Bio-processing of biomass to products.
- **Waste to energy -**
- Biomass to Briquette Manufacturing
- Biomass to Pellet Manufacturing

Recommendations for Construction and Demolition Waste -

- Facilitate segregation of construction and demolition waste at source to encourage reuse or recycling of materials, thereby avoiding inappropriate dumping.
- Demolish old existing structures or interiors sustainably and maximize resource recovery.
- Encourage practices that reduce waste generation during material handling and construction.
- Encourage reuse of the waste materials generated within the project.
- Encourage responsible handling of construction waste and recycling of the waste materials through authorized recyclers.
- Handover the remaining waste products and materials after reuse to the authorized recyclers.
- Ensure proper storage, transportation, and disposal of construction and demolition waste as per Construction and Demolition Waste Management Rules, 2016.
- Initiate awareness amongst occupants, workmen and stakeholders.

Recommendations for Abandoned vehicles -

- Guidelines for Maharashtra Vehicle Scrapping Facility Policy to be followed for abandoned vehicles.
- Collection And Dismantling of End-Of-Life Vehicles to be followed for abandoned vehicles.
- Identification of Creative Ways to Repurpose Old Cars
- Up cycling of car parts for innovative street and park furniture

Recommendations for Littering and Illegal Dumping of household and C&D Waste-

- Create awareness about littering and illegal dumping of waste using visible displays, posters, and awareness sessions.
- Create awareness and charge on the spot fines for disposing construction and demolition waste in the premises.
- Generate rules to prohibit the throwing, burning, burying and dumping of waste in vacant plots.
- Ensure surveillance of the neighborhood premises and common areas to avoid illegal dumping of mixed waste from the vicinity areas.

Recommendations for onsite location of Collection points, Storage containers for Waste Generated from open areas, vegetation, streets, alleys, parks, vacant plots etc.

- **Type of containers:**
- Waste collection containers for mixed waste - stationary containers: Multi Bin Systems: with movable lids.
- For Biomass Collection - hauled/ movable container: single bin - closed or with lids

Location of containers:

- Distance between containers on the roadsides, parks, alleys, internal roads and play areas- 100 to 200 meters
- Larger distance between the container and the source of generation will discourage people from dumping the wastes into the container.
- Location can depend on the, width and length of the road, Ease of collection vehicle to reach the containers, amount of waste generation and type of source generation

7. Conclusion

A multifaceted approach to overcome the challenges for solid waste management and recommendations scientific methods for resource & energy recovery is an important aspect for efficient waste management. Implementation and execution of zero waste concepts and demonstration of zero waste strategies for the Case of DSK Vishwa, Pune is an effort to reduce the amount of waste created and to ensure a proper waste management system in place. It is very vital that all the stakeholders involved in the selected neighborhood have an imaginative approach to overcome existing challenges faced and achieve efficient and zero waste management for the Case of DSK Vishwa, Pune.

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Need for senior citizen friendly Neighbourhood parks

Padma Shimpi

Abstract:
Background: Population of senior citizens in the neighbourhood is increasing rapidly. Mental health of seniors is important ,as with age, physical disability, health deterioration and navigating through different activities becomes challenging. Designing children play activities in public parks should be suitable for senior citizens who at times accompany them to the parks. Relationship of travel time activity and physical fitness, preference for the type of open spaces in public parks by senior citizens will give better insight in designing public parks.

Methods: Studies have to be focused on age groups above 55 years for both genders, senior citizens having physical disability. Criteria to select activity is based on Behaviour or activity in the public park which can be frequently observed in the park. The preference of senior citizens to different parks in the neighbourhood based on accessibility, cultural background. Studying the existing infrastructure in parks with respect to activity of senior citizens will give insight into the constraints faced by them in the public parks. Satisfaction of users by making surveys, questionnaire, observations will result in co relating the accessibility and usability of spaces in park.
Aim of the study is to understand the existing open space for senior citizen provided in parks and the activities suitable to the spaces in the given environment. Methods used in research will be survey considering a sizeable population of senior citizens above 55 years for both genders, at various time periods to understand their activity in relation to open spaces. Certain constraints being accessibility from home environment to the public parks, heavy traffic flow on access roads which concern the safety of the senior citizens, utilization of spaces designated for senior citizens in morning and evenings.

Methods
Going through research papers on similar studies regarding open space and senior citizens association with public parks. Studies have to be focused on age groups above 55 years for both genders, senior citizens having physical disability.
Senior citizens with severe disabilities are not a part of the study.
Case study method-literature review of similar case studies associated with senior citizen accessibility to public parks and their preference was reviewed to understand the current parks under study.

Results
Survey with questionnaires shared in google format with senior citizens resulted in preference of linear garden along the main road which ensured safety and more people and activity happening in the park. Observation of linear park in morning and evening had variation in the number of occupancy. Evening sufficient lighting and efficient road pedestrian crossing ensured easy accessibility of the park through the entire length.

Keywords:
Senior Citizens, Neighbouhood, Public Parks, Activity Pattern, Age Friendly Communities, Senior Out Door Activities, Mental And Physical Health, Motivation For Park Use, Physical Activity, Outdoor Nature, Pedestrian Accessibility, Urban Parks,.

1.Introduction

Population of senior citizens in the neighbourhood is increasing rapidly. Mental health of seniors is important as with age, physical disability, health deterioration and navigating through different activities becomes challenging. Depression due to managing things alone or being dependent on people for activities, social isolation with different age groups like children, youth and youngsters, lack of physical activity are few challenges in their path. Large areas of open spaces provide leisurely spaces for seniors to spend their morning and evening time in the park.
Designing children play activities in public parks should be suitable for senior citizens who at times accompany them to the parks. Urban parks provide physical and mental health for the senior citizen population. Major challenge faced is to provide accessibility to parks which are accessed from service roads. Suitability of public parks for senior citizens to enjoy their leisurely activities is the need of the society.

Municipal corporation is allocating open space areas in the neighborhood which are accessible to all age groups. The development plan of PCMC has allocated open space of more than 5 acres in the areas near residential development to reduce the negative impact of pollution and noise in the environment. By making the neighborhood parks easily accessible can increase the physical activity and interaction with society and each other thereby maintaining their physical and mental health. Relationship of travel time activity and physical fitness, preference for the type of open spaces in public parks by senior citizens will give better insight in designing public parks.

Physical inactivity is the major cause for diabetes, stroke and cardiovascular diseases. Place of residence and neighborhood environment affect the usage of public parks by the senior citizens. Accessibility to market, shops and temples on the route gave additional interest to the seniors accessing the public parks. Creating supportive environments like wider pathways with seating spaces has the potential for more pedestrian accessibility.(Billie Giles-Corti Ph.D. 2, Robert J. Donovan Ph.D.) Neighborhood context influences health behaviors like walking.(Catherine E Ross)As parks are used by younger and older people, integration of spaces is required for better utilization of spaces.(Angela Kreutz).Seniors aged 65-85 years and students aged 6 to 14 years were considered. Investigating park views and various elements like waterbody, plantation can give better insight for integrating the spaces.

Significance for students was playing, improving mood, learning. For seniors exercising, observing nature and meeting people. Landscape dominated by informal spaces that are home to native plants.(Baur et

al., 2013)Urban parks act as open community centre that bring sense of belonging among the people.(Alice Sabrina Ismail).Parks were originally designed for leisure, recreation, and a chance to make contact with nature, not to specifically promote physical activity.(Olmstead F. Public Parks and the Enlargement of Towns. In: LeGates RS,F, editor. The City Reader. Second ed. Routledge; London: 1870. pp. 314–320. [Google Scholar] [Ref list])Given high levels of inactivity and associated chronic diseases, like heart disease, diabetes, and cancer,1 it is timely to reconsider parks and their potential to improve the nation's health.(U.S. DHHS. Physical Activity Guidelines for Americans. U.S. DHHS; Washington, DC: 2008. [Google Scholar] [Ref list]).

A challenge in such studies is how to identify natural/green spaces and to capture their attributes. Previous studies have employed overall "greenness" without specific park attributes, only examined access (distance) to parks, or focused on one park used by participants. This study identified three types of neighbourhood parks residents may visit for recreation (most attractive, largest, closest), and examined what attributes of these parks are associated with leisure-time walking.

Criteria to select activity

- Behavior or activity in the public park.
- Frequently observed in the park.
- Well established effect on health physical or mental.
- By choosing visible behaviors we can understand neighborhood context for public parks.

We can study two aspects of physical exercise., walking and strenuous exercise. Walking and moderate, non aerobic exercise is the most common physical activity observed. Walking reduces obesity, back pain, osteoporosis, high blood pressure etc.,(Caspersen et al., 1992, Duncan et al., 1991, Magnus et al., 1979, Ross and Wu, 1995, US Preventive Task Force, 1989).Contagion behavior states that people are influenced by people around them copying their behavior so that it spreads.(Crane, 1991, Jencks and Mayer, 1990People who are afraid of streets near their house, who fear being robbed, attacked are afraid to leave the house.(Ross, 1993)

Neighborhood parks are considered the backbone of park systems. They often contain multiple diverse facilities—playgrounds, picnic tables, basketball courts, green spaces, and shade trees-- allowing residents of all ages to recreate there on a routine basis. Neighborhood parks are usually between 2 and 20 acres, have more facilities than mini-parks, and are intended to serve local residents living within a 1-mile radius around parks.

Funding for park programming, maintenance, and capital improvements is typically allocated from city budgets, which also vary across jurisdictions. It is plausible that local park management practices and policies could influence population-level physical activity. Prior studies indicate that sociodemographic, size, facilities, aesthetics, and proximity are all important factors contributing to park use.
Giles-Corti B, Broomhall MH, Knuiman M, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med.* 2005;28(Suppl 2):169–176. http://dx.doi.org/10.1016/j.amepre.2004.10.018. [PubMed] [Google Scholar] [Ref list]Parks between 3 and 20 acres were initially targeted.

Methods

Going through research papers on similar studies regarding open space and senior citizens association with public parks. Studies have to be focused on age groups above 55 years for both genders, senior citizens having physical disability. Senior citizens with severe disabilities are not a part of the study. Case study method-Research papers on case study of Urban parks were reviewed.one of the parks from the 10 parks selected in the neighborhood was selected for detailed survey and observation for different activities in the park. Morning and evening time were considered for the observation. Layout of the parks were studied, various landscape and activity zones were identified. Mapping of senior citizens in the park was done with the help of dot method.

Study area

PCMC region having many public parks allocated in residential zones and along main roads are developed in terms of infrastructure and landscape. Gardens frequently visited for senior citizens were listed out and observed to understand the various activities of the senior citizens. Due to road accessibility, proper pedestrian crossings and peaceful environment these parks were preferred by the seniors for morning and evening walks. The total sample size were 50 respondents distributed in the different parks. PCMC linear park-pimple saudagar, Atal Bihari Vajpayee park, PCMC playground-Kunal Icon road, Rajmata Jijau garden-dinosaur park Sanghvi were considered for study.

F2: Linear garden and Shree Sambhaji Maharaj PCMC Garden. Savitribai Phule Park,Jagtap diary

F3: PCMC Playground, Kunal Icon Road, Pimplesaudagar

Data collection

An interview schedule was prepared with basic questionnaires about the age, gender, park preference, and different activities in the park in English. Where language was a barrier it was translated to the respondents and forms filled. Google forms were distributed to respondents and their preference was tabulated in excel sheets. By having a friendly dialogue with the respondents, interviews in the morning from 7 to 9 am and evening 5 to 7pm were conducted

All parks selected are in PCMC areas having large designed landscape spaces above 5 acres. Pune having a moderate temperature, public parks are occupied most of the year except for the rainy season in July. The above parks considered in the study have a variety of designed spaces sharing the same cultural context within 2km radius of each other. Large residential and commercial areas near the park attract large crowds. Majority of the crowd were seniors above 60 years of age.

F4: Gyanjyoti Savitribai Phule Udyan

F5: Rajmata Jijau garden, Sanghvi

Various parameters like green areas, waterbody, hardscape, Fitness ground, inviting main entrance and sculptures add to the interest of the park visitors. Behavioural Mapping-Observation and recording behaviors of seniors in public parks in specific zones having comfort to them were identified in the different parks. Standing point of the observer did not disturb the privacy of visitors. Mapping was carried out with dots based on the number of individuals, genders, age groups and activities.

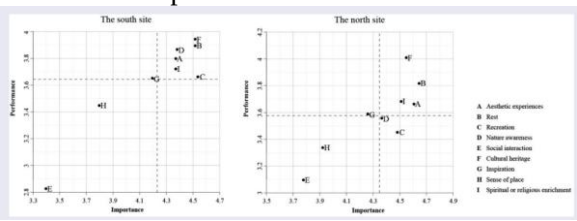
Table -1: Distribution of respondents in various parks

Category	Sub category	% percentage
Sex	Male	50
	Female	50
Age	60-70	90
	70 and above	10
Time spent	0-30 minutes	
	30min to 1 hr	
	1hr and above	

Reasons for visiting	Physical therapy like walking	60
	Exercise equipments	30
	celebrations/cultural festivals	10

Case study 1-Gyanjyoti Savitribai Phule Udyan (800m loop)
Case study 2-Linear Garden, Pimplesaudagar (640m loop)

Data Analysis
Layout of the different parks in the neighborhood were studied and site area, tree canopy, lawn area, paved areas, and different activities were demarcated. Activity mapping in areas of the park where senior citizens preferred walking, exercising were demarcated on the layout. Surrounding land use near the parks having an impact on preference was studied.
Importance performance analysis format can be helpful in analyzing the public park and senior citizen utilization of spaces.



Reference: a Department of Urban and Regional Planning, Peking University, Beijing, China; b Department of Architecture, Shanghai University,

Importance performance analysis first proposed by Martilla and James is a useful tool in measuring how people feel about certain thing. The purpose of the study was to understand senior citizen usability of parks during morning and evening hours based on comfort and landscape spaces in the park.

Table-2
Examples of research in Urban green space

Reference	Description	Approach	Country
Nurhayati Abdul Malek[1]*, Manohar Mariappan[2], Mustafa Kamal Mohd Shariff[3], Azliza m Aziz	Quality public space offers physical and mental health benefits to our nation's aging population, but there is work to be done to optimize the suitability of greenspace for diverse older adults.	This review will only include studies that are reporting the impact or effects of green spaces on quality or success of green open spaces within residential areas, preferences factors, human needs factors, use pattern and user focus or users and visitors in general.	Malaysia
Nurhayati Abdul Malek(October 2011)	A lot of people share common needs, but by identifying each person's unique needs will help answer why people use a particular space in the first place.		Australia
Nurhayati Abdul Malek[1]*,	Generally, public open spaces near homes are used for leisure activities, work, gatherings, educational projects and much more (Hester, 1984). Earliest studies too have indicated that there are several important observable factors that influence the use in a neighbourh	Among the external factors are surrounding neighborhood factors; social diversity of park users; the strong neighborhood and community group; and a well-established advisory council. For the internal factors, the physical design of the park plays an important role as well as management of the park and finally supervision of its users and park management are	Malaysia

	ood space.	the key role in ensuring a park is successful in serving its diverse users	
Deborah A. Cohen, MD,1 Bing Han,	174 neighborhood parks in 25 major cities (population >100,000) across the U.S. was selected. Park use, park-based physical activity, and park conditions were observed during a typical week using systematic direct observation during spring/summer of 2014. Park administrators were interviewed to assess policies and practices	the average neighborhood park of 8.8 acres averaged 23 users/hour or an estimated 1,533 person hours of weekly use. Walking loops and gymnasia each generated 221 hours/week of moderate to vigorous physical activity. Seniors represented 4% of park users, Parks were used less in low-income than in high-income neighborhoods	US

Types of Neighbourhood Parks

A neighborhood according to Hester (1984) is a focal point, such as school and recreational area, where each house should be adjoined to a planned open space area. A neighborhood park according to Chapman (1999) is a place where diverse needs are met without the necessity of traveling a long distance, providing basic recreational amenities for all users; it is also usually located within the center of a development. Similarly, Von Kursell's (1997) thesis defines Neighbourhood Parks as places which serves both active and passive recreation providing a local park function and facilities to a wide range of people. Usually, it contributes to an area of 0.5-to-0.8-kilometer radius or catchment area.

Neighborhood parks in this context will refer to specific pockets taken up for study and frequently visited by senior citizens. Dependent variables are using pattern, needs, preference. Neighbourhood parks are basic units of a park system. Green natural landscapes and less walking distance promotes accessibility to the parks. Surrounding land use like temples, weekly markets, eating joints add to the advantage of location of public parks. Parks more than 5 acres and more are called neighbourhood parks.

Natural surrounding

Among authors discussing factors of natural surroundings includes (Van Herzele's study, 2003) which implies that the amount and quality of green spaces will affect citizens' activity patterns, frequencies of every day recreation, opportunities to relax from daily stress as well as the way knowledge about the environment is acquired.(Neuvonen, Sievanen, Tonnes, and Koskela, 2007) Their study among Helsinki's residents shows that close-to-home nature should be an indicator of the success for planning a new housing areas as well as developing old suburbs where the green environment should be valued as a remarkable source of health and well-being for the residents to help achieve more satisfying and happier lives. Incorporating a large number of native plants in the park will benefit the micro climate and ambience of the park. Disparities in park use based on gender, age, background, cultural impact can be observed in neighborhood parks.

Spaces designed in parks

Subsequently, a study in Norwich, England by (Hillsdon, et al., 2006) looked into the association between access to quality urban green space and levels of physical activity. Hillsdon's study developed and reviewed new measures capturing aspects of green space, among others are accessibility, maintenance, recreational facilities, amenity provision, signage and lighting, landscape, usage and atmosphere. Their findings indicate that middle- aged men and women were not directly associated with the amount of physical recreational activities done per week as well as their access to any large, quality, urban green spaces. Study of energy levels of seniors in public parks with respect to activity, time period and frequency can be observed.

Limitations

Observing activity for each season on weekdays and weekends was not considered in the study. Late afternoon activities in the parks along roads which were accessible were not taken into study. Large shady trees and seating spaces were conducive for the seniors to take rest or have social interaction. As it is not under leisure activities in the parks and very few senior citizens accessing the parks, it was not included in the

study. Adults who could read and were aware about health benefits responded more to questionnaire than family members helping them to respond.

Conclusions

Because of the varied locations of the parks we conclude that interventions promoting public park design to make it accessible to senior citizens should have larger unobstructed areas and easy pedestrian accessibility. The areas dedicated for physical activity like walking can be smaller in loop with seating spaces for rest at intermediate places in the park. Proper signals and pedestrian crossings aid in seniors accessing the park for outdoor exercise equipments. For planning urban park the activities and spaces highlighted in the case study can be effective in designing future urban parks in the neighbourhood.

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Environmental Psychology: An Important Factor in Sustainable Development

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Abstract:
The convergence of environmental psychology and sustainable development is a critical nexus in tackling the world's complicated difficulties. Understanding the delicate interaction between human behaviour and the environment is becoming increasingly important as countries cope with the mounting impacts of climate change, resource depletion, and biodiversity loss. This paper investigates environmental psychology's varied significance as a critical aspect in furthering sustainable development. Environmental psychology studies how people perceive, interact with, and are influenced by their environment. Recognizing the deep impact of these interactions on human well-being and environmental sustainability is critical to establishing happy cohabitation between society and nature. The paper digs into essential subjects such as environmental attitudes' psychological components, pro-environmental behaviour, and the influence of the built environment in shaping sustainable behaviours.
The paper also emphasizes the reciprocal aspect of individuals' relationships with the environment, emphasizing how the status of the environment can influence human cognition, emotion, and behaviour. Environmental psychology insights provide significant views for designing treatments, policies, and urban planning methods that encourage environmentally responsible behaviour and contribute to the larger aims of sustainable development practices.
This paper highlights the importance of bringing psychological concepts into the discussion of sustainability by clarifying the psychological foundations of environmental issues. It is possible to cultivate a more fundamental and enduring commitment to responsible environmental stewardship by incorporating environmental psychology into sustainable development activities. This will ultimately pave the path for a resilient and sustainable future.

Keywords:
Environmental Psychology, Sustainable Development, Human-Environment Interaction, Built Environment

Introduction

India, like with numerous other nations, has incorporated the Sustainable Development Goals (SDGs) into its domestic development plan. Several of these objectives are directly linked to urban planning and tackle the issues and possibilities connected to sustainable urban development. Two crucial Sustainable Development Goals (SDGs) that are pertinent to urban development in India are as follows: Goal 11: Sustainable Cities and Communities; Target 11.1: Ensure access for all to adequate, safe, and affordable housing and basic services and upgrade slums & Target 11.3: Enhance inclusive and sustainable urbanization and capacity for participatory, integrated, and sustainable human settlement planning and management. Goal 16: Peace, Justice, and Strong Institutions: Target 16.7: Ensure responsive, inclusive, participatory, and representative decision-making at all levels.

Within the complex realm of urban planning, planners often have a tendency to occasionally neglect the fundamental aspect: the individuals who reside in these areas. There is often a prioritization of economic and environmental factors, resulting in a disregard for the human element in the construction of our surroundings. Urban planners, motivated by economic imperatives or aspirations for environmental sustainability, may unintentionally overlook the varied requirements, desires, and everyday encounters of the community. Urban environments may exhibit a deficiency in cultural significance and inclusiveness, which are necessary for the development of prosperous societies. Gaining insight into the community's perception and utilization of public spaces is crucial for effectively strategizing the long-term maintenance and adaptability of these areas. Sustainable urban planning entails the development of areas that adapt to the dynamic requirements and preferences of the population.

This paper helps Designers acknowledge that the success of urban planning goes beyond economic benefits and environmental factors; it relies on building spaces that deeply connect with the individuals who inhabit, work, and engage in recreational activities within them. In order to rectify this omission, it is crucial to undergo a fundamental change in approach, prioritizing the design of urban spaces around the needs and experiences of individuals. This will guarantee that the constructed environment not only supports economic and environmental goals, but also enhances the quality of life for its inhabitants.

This study tries to highlight how significance of people's psychology in urban planning initiatives is crucial for various reasons, underscoring the necessity for an approach that prioritizes the user and community. An individual's well-being and quality of life are

directly impacted by their impressions of their environment. Urban planning initiatives that take into account elements such as visual appeal, security, and ease of use play a role in establishing environments that have a beneficial effect on the mental and physical well-being of inhabitants.

The increasing difficulties presented by climate change, depletion of resources, and loss of biodiversity require a thorough comprehension of the complex connection between human behaviour and the environment. The intersection of environmental psychology and sustainable development arises as a crucial field of research to effectively tackle these global challenges. This study aims to explore the diverse importance of environmental psychology in promoting sustainable development while planning a urban space. The main goals are to investigate the psychological aspects of environmental attitudes, comprehend pro-environmental behaviour, and examine how the built environment impacts the development of sustainable behaviours.

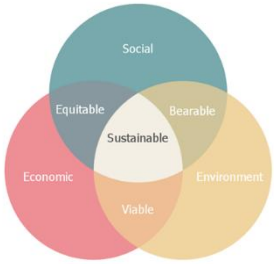
A literature review serves as key purpose within the methodology section of a research paper. The systematic analysis of existing scholarly articles and research papers relevant to the topic will help us understand the concept of Environment Psychology and its importance in sustainable development.

1. Sustainable Development

The Concept of Sustainable Development

The term 'Sustainable Development' was coined in 1987 by the Brundtland Commission, formally known as the World Commission on Environment and Development, The United Nations General Assembly founded it in 1983. In the 1980s, global leaders developed a heightened awareness of the rapid degradation of the environment caused by excessive exploitation of nature by humans.

Sustainable development is a guiding philosophy that seeks to achieve human development objectives while also ensuring that natural systems can continue to supply essential natural resources and ecosystem services to humans. The objective is to establish a society in which the living circumstances and resources adequately fulfil human need without compromising the overall integrity and stability of the natural system. Sustainable development aims to achieve equilibrium among economic advancement, ecological preservation, and societal welfare. The Brundtland Report, published in 1987, established the concept of sustainable development as the pursuit of development that fulfils the requirements of the current generation while safeguarding the capacity of future generations to fulfil their own needs. Currently, the notion of sustainable development emphasizes the advancement of the economy, society, and the safeguarding of the environment for the benefit of future generations.



F1: The Concept of Sustainable Development.

The Sustainable Development Goals

The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, which were approved by world leaders in September 2015 during a significant UN Summit, formally became effective on 1 January 2016. In the upcoming fifteen years, nations will endeavor to eradicate all manifestations of poverty, combat disparities, address climate change, and ensure inclusivity through the implementation of these comprehensive Goals that are applicable to all.

The SDGs, or Sustainable Development Goals, expand upon the achievements of the Millennium Development Goals (MDGs) and strive to eradicate all manifestations of poverty. The new Goals are distinctive in that they require active participation from all nations, regardless of their economic status, to foster economic well-being while safeguarding the environment. They acknowledge that eradicating poverty must be accompanied by methods that foster economic development and fulfil many social requirements such as education, healthcare, social security, and employment opportunities, while simultaneously addressing climate change and environmental preservation.

The SDGs are designed to be interconnected and integrated, emphasizing the need for comprehensive and collaborative efforts by governments, businesses, communities, and individuals. The goals aim to achieve a more sustainable and inclusive future by 2030.

F2: The Sustainable Development Goals

2. Environmental Psychology

The Journal of Environmental Psychology defines the field as, "The field of research that examines the interactions and connections between individuals and their physical surroundings, encompassing both constructed and natural habitats, the exploitation and misuse of nature and its resources, and behaviour connected to sustainability."

Environmental psychology focuses on the dynamic relationship between individuals and their surroundings. As a discipline, it aims to comprehend the influence of our surroundings on us, how we might exploit that understanding for our benefit, and how we can enhance our connection with the surrounding world.

Origins and Initial Impact

Environmental psychology originates from the wider disciplines of psychology and environmental studies. The period between the late 1960s and early 1970s witnessed the establishment of environmental psychology as researchers-initiated investigations into the psychological effects of individuals' interactions with their environment. Environmental psychology sought to establish a connection between the natural and social sciences, drawing inspiration from disciplines like sociology, architecture, and urban planning.

First Settlers

Rachel Kaplan is a prominent figure in the field of environmental psychology. Together with her husband Stephen Kaplan, she made substantial contributions to the comprehension of environmental choice and the rejuvenating impacts of nature. The Attention-Restoration Theory argued that being in natural environments can restore cognitive resources and enhance concentration.

Roger Ulrich's seminal study in 1984 showcased the beneficial impact of natural vistas on patients' recuperation in hospitals, underscoring the practical applications of environmental psychology in healthcare environments.

Core Ideas and Fundamental Principles.

Environmental psychology involves several fundamental concepts, such as environmental attitudes, place attachment, and the influence of design on well-being. The discipline acknowledges the significance of studying both natural and constructed surroundings, while recognizing the influence of cultural, social, and historical elements in creating individuals' experiences. Edward O. Wilson created the notion of "biophilia" in the 1980s, which proposes that people have an inherent inclination towards nature. This concept has had a significant impact on environmental psychology, highlighting the psychological and physiological advantages of integrating natural elements into constructed surroundings.

Evolution and Current Viewpoints

Environmental psychology emerged as a response to the psychological consequences of climate change, resource depletion, and urbanization, which have become significant global concerns. Researchers are increasingly directing their attention towards comprehending pro-environmental behaviour, delving into methods to inspire individuals and communities to embrace sustainable activities. Modern environmental psychology encompasses the study of technology, examining the psychological effects of virtual environments and the influence of digital platforms on the formation of environmental beliefs. The discipline has broadened its scope to tackle the difficulties of establishing robust communities in response to climate-induced occurrences and ecological catastrophes.

Literature Review

The literature review section presents two pertinent studies. Karl Samuelsson's initial study delves into the influence of environmental characteristics on individuals' daily encounters in Stockholm. It highlights the significance of incorporating environmental characteristics into urban development to promote human welfare. Prof. Tana Trivedi's second study examines the socio-economic consequences of the Sabarmati Riverfront on displaced populations. It emphasizes the difficulties and deficiencies in the execution of the Resettlement and Rehabilitation (R&R) policy.

The research authored by Karl Samuelsson and his colleagues, entitled "Impact of environment on individuals' daily experiences in Stockholm," investigates the potential of urban environments to promote human welfare while mitigating adverse effects on global sustainability.

The study examines the accessibility of seven environmental characteristics throughout the Stockholm municipality.
The features include:

1. The number of people living in residential areas.
2. Employed individuals
3. Natural habitats
4. Recreational areas and educational facilities for children
5. Aquatic environments 6. Primary transportation routes
7. Local implementation of natural temperature regulation

The accessibility of these features is determined by quantifying the distance one must walk to reach them within a 500-meter radius from a specific point of measurement. The study employed a grid with a resolution of 10 meters, covering all land surfaces within the study region. The measurement points were located at the centers of each grid cell. The accessibility research was performed via the Place Syntax Tool.
The residential and working populations' accessibility was determined by calculating the number of people located within a 500-meter walking distance. The proximity to the nearest feature within a 500-meter radius was determined for natural landscapes, playgrounds, water bodies, and major roadways. The local provision of natural temperature regulation was measured by calculating the average capability for regulating temperature within a 500-meter radius.
This methodology for a systematic examination of the accessibility of these environmental characteristics throughout the entire municipality, yielding valuable observations regarding their potential impact on individuals' experiences in various regions of Stockholm.

The likelihoods of favorable and unfavorable experiences in various locations were calculated by employing spatial regression to extrapolate from the findings of an online Public Participatory GIS (PPGIS) survey, which took into account the environmental characteristics. The PPGIS survey gathered 1784 instances from 1032 participants, and the spatial regression model was employed to calculate the likelihood of cells offering happy experiences instead of negative ones. The model considered the influence of environmental characteristics on the experiential results, while also taking into consideration the spatial autocorrelation among the data.

The primary discoveries derived from the PPGIS survey and the spatial regression analysis encompass:

1. Out of the seven environment elements that were evaluated, six of them have a substantial influence on experience results.
2. The quantity of inhabitants and the closeness to natural surroundings and water, which are typically regarded as indices of quality in urban planning and research, have limited but statistically significant impacts on individuals' experiences.
Areas with a high concentration of workers or close to main roadways had significantly lower rates of positive experiences, whereas areas with a great capacity for managing natural temperatures have significantly higher rates.
4. The findings reveal significant variations in quality between urban and natural habitats, emphasizing the importance of urban planning strategies that recognize these distinctions in order to enhance human welfare while minimizing harm to the biosphere.

These findings highlight the need of taking into account the impact of environmental characteristics on individuals' experiences. They also propose that urban design should incorporate both proximity to urban areas and access to everyday natural experiences in order to promote human wellbeing in urban settings.

The research authored by Prof. Tana Trivedi and colleagues, titled "A Study on Socio-Economic Impact of Sabarmati Riverfront on Life of Displaced Communities," examines the socio-economic effects of the Sabarmati Riverfront on the lives of populations that have been displaced. The study examines the difficulties encountered by families that were displaced as a result of development initiatives, namely in the Vatwa region.

The Study identified various social and economic transformations in the community that had been relocated after displacement:
1. Livelihood Disruption: A significant number of resettled families faced adverse effects on their means of making a living. Many expressed feelings of animosity and raised doubts about the benefits of resettlement, as they encountered more difficulties in sustaining their livelihoods.
2. Shift in Employment Patterns: The displacement caused a shift in employment patterns, as numerous families were compelled to switch jobs. This resulted in job discontent owing to inadequate remuneration and increasing commuting distances.
3. Educational Impact: The displacement resulted in a notable decline in the enrollment of children in schools, indicating an adverse effect on education.
4. Housing and Facilities: Although the families that were transferred did benefit from enhancements in fundamental amenities and housing, there were worries regarding employment prospects, income, and the availability of crucial services.

The observed alterations highlight the intricate social and economic consequences of displacement on the impacted communities.
The Resettlement and Rehabilitation (R&R) policy sought to tackle the difficulties encountered by the urban underprivileged population who were relocated, employing various strategies:

1. The strategy aims to offer enhanced housing, essential amenities, and infrastructure at the resettlement sites in order to improve the living conditions of the displaced families.
2. The objective was to guarantee access to vital services, including healthcare and education, by

implementing sufficient provisions in the resettlement zones.
3. Livelihood Support: The objective of the R&R programme was to assist the relocated families in sustaining their livelihoods by creating avenues for employment and generating money in the new areas.
4. The strategy sought to offer legal safeguards and aid to the displaced families, guaranteeing equitable treatment and help throughout the relocation procedure.

However, the study identified difficulties and deficiencies in the execution of the R&R strategy, emphasizing the necessity for additional enhancements to adequately tackle the socio-economic consequences of relocation on urban impoverished groups.

To summarize, the study provides a thorough and integrated examination of environmental psychology, sustainable development, and urban planning. It highlights the significance of incorporating psychological principles into discussions about sustainability and urban development in order to establish resilient and sustainable futures. The referenced papers offer pragmatic perspectives on the difficulties and possibilities linked to urban planning and relocation, underscoring the necessity for inclusive and human-focused methodologies.

Inference

The integration of environmental psychology into urban planning is crucial for architects aiming to promote sustainable development. Here are several reasons highlighting the importance of incorporating psychological principles into the urban planning process:

1. Human-Centered Design:

Environmental psychology prioritizes a human-centric perspective, taking into account the requirements, actions, and encounters of the persons who occupy a particular environment. Architects may improve the quality of life, promote well-being, and encourage a feeling of community by studying how people interact with their surroundings and designing urban areas accordingly.

2. Behavioral Change for Sustainability: Sustainable development hinges on the ability to influence human behaviour towards the adoption of environmentally beneficial practices. Environmental psychology offers valuable insights into the factors that drive and maintain good changes in behaviour, such as promoting the use of public transportation, reducing waste, and improving energy efficiency. Architects have the ability to create urban environments that prioritize sustainability and make it simpler and more attractive for citizens to adopt sustainable practices. Urban areas that are carefully planned and built have the potential to enhance social cohesiveness and foster community participation. Architects may design places that foster connections, communication, and a feeling of belonging among residents by comprehending the psychological dimensions of social interaction. Robust social connections can contribute to the development of a community that is more enduring and adaptable.

3. Stress Reduction: Urban settings frequently encounter obstacles such as excessive noise, congestion, and pollution, which can lead to heightened stress levels and diminished overall well-being. Architects can utilize concepts of environmental psychology to create urban settings that alleviate these stressors, fostering mental well-being and enhancing total community resilience. Environmental psychology emphasizes the significance of nature in human well-being, specifically in terms of biodiversity and its integration. Architects have the ability to integrate green spaces, parks, and sustainable landscaping into urban design. This allows citizens to have access to nature, which has been proven to decrease stress, improve mood, and contribute to a more sustainable and resilient urban environment.

4. Community engagement and ownership: The active participation of the community in the planning process is essential for the successful implementation of sustainable development initiatives. Architects can effectively involve communities, gain support, and guarantee that urban planning projects match with the values and ambitions of the local population by comprehending the psychological dynamics of community engagement.

5. Adaptive Urban Design: Environmental psychology highlights the capacity of the constructed environment to adjust to evolving requirements and conditions. Architects possess the ability to create adaptable and adaptable urban environments that can adapt and endure in the face of forthcoming difficulties, such as population expansion, climate change, and technology progress, so ensuring the city's sustainability and resilience.

Architects who include environmental psychology into urban design enhance the development of cities that are more sustainable, resilient, and habitable. Architects may cater to the distinct requirements of communities, encourage sustainable behaviours, and design urban environments that improve the overall well-being of citizens and preserve the planet for future generations by taking into account the psychological components of human-environment interaction.

Conclusion

In conclusion, the significance of environmental psychology in sustainable development cannot be exaggerated. In light of the extraordinary environmental issues our planet is currently confronting, it is crucial to comprehend the deep correlation between human behaviour and the environment in order to develop efficacious and

enduring remedies. Environmental psychology offers useful insights into individuals' perception, interaction, and influence on their surroundings. This knowledge forms the basis for creating sustainable interventions and policies. By integrating psychological principles into sustainable development programmes, we increase the likelihood of promoting significant behavioral changes and nurturing a shared awareness that emphasizes the welfare of both individuals and the environment. Environmental psychology plays a vital role in this comprehensive approach, leading us towards a balanced and mutually beneficial relationship with the environment, and facilitating the development of a more sustainable and adaptable future.

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Design Criteria of Sustainable Urban Park in Pune

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Abstract:
This study investigates the exploration of design criteria for sustainable urban parks. There is no example, today, where all the proposed sustainable design criteria are applied together in a specific urban park. The design of urban parks plays a crucial role in creating sustainable and livable cities. The research suggests several design criteria for sustainable urban parks. These include integrating green infrastructure, creating accessible and inclusive designs, incorporating multi-functional spaces, using native and adaptive plant species, and employing sustainable materials and construction methods. By incorporating these principles into park design, cities can create vibrant and healthy green spaces. The study also examines the benefits of including sustainability principles in urban park design and analyzes case studies of existing sustainable urban parks. The aim is to provide practical visions and recommendations for landscape architects and urban planners to enhance future park design activities. Ultimately, integrating sustainable design criteria in urban parks contributes to the overall sustainability and livability of cities. The goal of this research is to inspire and guide the development and improvement of urban parks to create healthier and more robust urban environments for residents to enjoy. This research aims to investigate how urban parks contribute to helping cities become more sustainable, define a sustainable city and its design principles, Outline the role of urban parks as part of the green infrastructure of the city, and identify the core sustainable design objectives of urban parks. The research findings from this study can make a valuable contribution to the implementation of comprehensive sustainable park design practices in our cities in the future. By integrating these findings into park design, we can create more environmentally friendly and socially inclusive spaces for our communities.

Keywords:
Sustainable Criteria, Parks, Native Plants, Green Infrastructure.

Introduction

Urban parks play a crucial role in the development of sustainable and eco-friendly cities, serving as valuable contributors to cleaner air, recreational green spaces, and wildlife habitats. To enhance the sustainability of urban parks, certain measures need to be taken. The inclusion of natural areas and open spaces is of growing importance for enhancing the overall well-being of urban residents. Open green spaces provide not only aesthetic qualities but also significant ecosystem services and quality of life in the ever-shrinking environment of urban areas (Wu, 2014; Zerah & Landy, 2012; Woolley, 2003). When designing urban parks, it is crucial to address the challenges posed by urban population growth and ongoing environmental concerns. An urban park is typically located at a distance of 2-4 km from the city center and is accessible by public transport or within a 30-60-minute walking distance. The key objective should be to improve the physical and mental health of park users through sustainable urban design. Urban parks play an essential role in enriching the quality of life in cities by offering open green spaces for recreational, social, and environmental purposes. These parks also serve as active gathering spots for local communities, providing opportunities for relaxation, physical activity, and cultural events. However, the design and layout of urban parks significantly impact their functionality, accessibility, and overall, success. Therefore, it is critical to create effective design criteria that address the various needs and expectations of park users.

Designing urban parks involves the careful consideration of various factors, including the park's location, size, layout, amenities, and ecological sustainability. These design criteria not only shape the physical attributes of the park but also influence its ability to accommodate different user groups, promote inclusivity, and meet the demands of a dynamic urban context. Another important design criterion is accessibility. Urban parks should be easily accessible to all members of the community, regardless of age, physical ability, or socio-economic background. The design criteria should highlight the social and cultural aspects of urban parks the design should facilitate these activities by providing flexible spaces that can contain various events, performances, and exhibitions. This research paper aims to define sustainability, urban parks and the key design criteria for creating sustainable urban parks and highlight their critical role in ensuring environmental balance and long-term environmental sustainability. In this research paper, we will investigate the design criteria of sustainable urban parks and explore how thoughtful planning and innovative approaches can help to create green spaces that enhance the quality of life for residents and promote environmental sustainability. Research on sustainable urban parks in Pune holds great importance

for several reasons. Environmental Impact: Comprehending the design and management practices of these parks is crucial in evaluating their ecological impact. This knowledge can be utilized to enhance and replicate sustainable park initiatives, resulting in improved ecological conservation and decreased carbon emissions.2. Urban Planning and Health and Well-Being: Investigating sustainable urban parks in Pune can contribute to urban planning decisions. The findings can inform policies concerning the allocation of green spaces, park development, and sustainable design principles, promoting a more environmentally-conscious and livable city. 3. Native plantation and the shaded portion: identifying the native species from Pune and in urban parks. In order to investigate: planning, management, development, and evaluation of a sustainable green space, this study reviewed the crucial dimensions of sustainability through environmental, social, physical, special and built characteristics, in the context of urban planning and design. **Problem statement: separation of humans and nature:** As settlements became bigger and more populated and nature was marginalized and neglected (Neil Stuart et al., 2013), Beyond aesthetic and health benefits of nature, natural features in cities can have other social benefits. (Coley et al)

LITERATURE REVIEW:

The research methodology involves a complete review of the literature, case studies of successful sustainable urban parks, and expert interviews. The literature review provides a theoretical framework by examining existing research on urban park design, sustainable development, and environmental considerations. In this study, a systematic literature review was carried out to identify and develop sustainable design criteria for urban parks.

The Benefits of Urban Parks, a Review of Urban Research:(Author: Sreetheran Maruthaveeran, Cecil Konijnendijk, Anders Busse Nielsen):
This report presents the findings of a major literature review relating to the benefits of urban parks. The review considers material from sources that include peer-reviewed literature, libraries and the internet. The results of the study revealed the benefits of urban parks in four categories. Environmental Benefits include Ecological Benefits, Pollution Control, Biodiversity and Nature Conservation. Economic Benefits include Energy Savings, Urban parks and water management, and Property Value. Social and Psychological Benefits including Recreation and Well-being, Human Health and Tourism reduce crime. Planning and design, including perceptions of green space, aesthetic values, and the planning and design of green space. Also, they have specified it in categories. Onijnendijk (2013).

The role of urban parks for the sustainable city: (Author: A. Chiesura):
This report presents the findings of a major literature review relating to the role of urban parks The paper is part of an EU-funded project aimed at investing in the intangible services of natural areas, and their immaterial benefits for Uman societies. Attention has been focused on urban nature, close to where people live and work. Public perceptions and attitudes have been explored among visitors of urban parks in three European cities: Amsterdam (the Netherlands), Paris (France)and Seville (Spain). Some results are emotions. Research mostly identifies These benefits are believed to improve the health and well-being of individuals, and consequently, the sustainability of the community at large. Implications for the sustainability of the city have been analyzed and discussed

The complex landscape of inequity in access urban parks: (author: Alessandro Rigolon):
The article reviews the increased literature on environmental justice which documents access to urban parks in all socioeconomic and ethnic groups. The extensive public health and sustainability benefits of parks, the extensive public health and sustainability benefits of parks, or combined with the long history of discrimination against people of color in the United States and elsewhere, motivate an update of the literature on access to parks. These findings are particularly concerning for public health because large, high-quality, well-maintained, and safe parks can better foster physical activity and its associated benefits than small parks with few amenities. Also, identifying inequities in access to parks based on proximity, acreage or quality can help develop targeted landscape planning strategies to address specific inequities.

Urban Green Space, Public Health, and Environmental Justice: The Challenge of making cities 'Just Green Cities':(author: Jennifer Wolch, Joshua Peter Newell, Jason Antony Byrne):
The essential ecosystem services are those provided by green spaces in cities, like parks, forests, roofs of streams and garden areas. Physical activity, mental well-being and general public health of the city inhabitants are also promoted by green spaces. This paper reviews the Anglo-American literature on urban green spaces, especially parks, and compares efforts to green U.S. and Chinese cities. The reasons why green spaces are differentially distributed within the urban landscape are varied, including the philosophy of park design, the history of land development, evolving ideas about leisure and recreation, and histories of class and ethno-racial inequality and state oppression (Byrne, 2012; Byrne & Wolch, 2009).

Characteristics of urban parks and heir relation of user well-being: (author: Cristina Ayala-Azcárraga's, Daniel Diaz, Luis Zambrano):

Research has evaluated perceived characteristics of green spaces and environmental components of urban parks as public urban green spaces, relating them to the well-being of their visitors. To find out the patterns of usage and their effects on citizen well-being, a study has been conducted among users of nine parks in Mexico City. The outcome shows that there is a strong relationship between visitor use with the components of urban parks including distance, tree abundance, safety, quality of playing fields and cleanliness. The variables that explain to visitors the comfort offered by the park are competent neighbors, trusted guests and sharing it with known people. It is therefore that perceptions of this park affect their use and provide several benefits to users' well-being.

Components of small urban parks that predict the possibility for restoration:(author: H. Nordh , T. Hartig , C.M. Hagerhall , G. Fry):
This study aims at evaluating the extent to which these elements individually and in combination are capable of predicting whether there is a potential for restoration within tiny urban green spaces. To understand how they might influence restoration likelihood, we refer to attention restoration theory (ART; Kaplan and Kaplan, 1989; Kaplan, 1995). ART focuses on supporting the restoration of a reduced capacity to take action, through environmental support. The theory characterizes restorative experiences in terms of being away, fascination, extent, and compatibility. Being out means psychological distance from the demands and activities of a person who uses his or her direct attention capacity. Fascination refers to the way in which elements such as flora and fauna, as well as the process of exploration, are attracting attention. the logic of mediation outlined by Baron and Kenny (1986), we assess the extent to which being away and fascination mediate the relations between park components and the likelihood of restoration.

AIM: Accessing design criteria of sustainable urban parks.

SUSTAINABILITY CONCEPT: This guide considers that a sustainable Community Park or landscape may be established where natural resources are protected, wildlife habitat has been improved and human use and maintenance practices do not harm the environment.

URBAN PARK CONCEPT: parks in cities and other incorporated areas that provide residents and visitors to the municipality with recreational and green space.

OBJECTIVE:
- Investigating. parks how contribute cities become can to helping more sustainable
- Out living the sole of urban parks as part of green. infrastructure of city
- Identifying direct health effects & indirect
- Identifying the effect packs prices. & of urban the nearly house

MATERIALS AND METHOD:
In the process of methods, here are some of the methods of research.
1) Literature Review: The research methodology involves a complete review of literature, case studies of successful sustainable urban parks, and expert interviews. The literature review provides a theoretical framework by examining existing research on urban park design, sustainable development, and environmental considerations.
In this study a systematic literature review was carried out to identify and develop sustainable design criteria for urban parks.
2. Case Studies: Analyze existing urban parks that have been familiar as sustainable models.
3. Comparative Analysis: Compared the different sustainable urban parks across locations, sizes, or various design elements. By investigative similarities and differences, identified the most effective design criteria applicable to different contexts and gain a broader understanding of their impact.
4. Participatory Design: Engage with the local community, park users, and stakeholders through participatory design workshops or charities.

DATA ANALYSIS:
As research follows a case study here are some case studies which had been analyze data:

OKAYAMA FRIENDSHIP GARDEN:

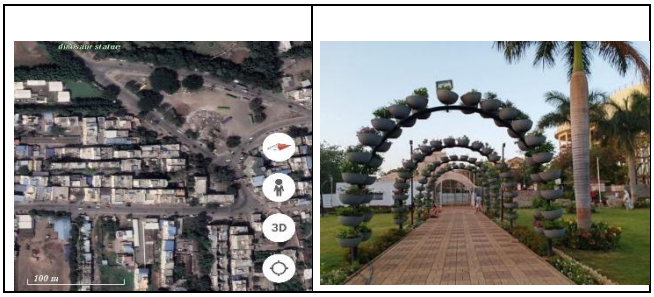
F1: mapping of park F2: park with water

Location-Pune Okayama friendship garden, Datta wadi, Pune, Maharashtra.
Built: 1700 OPEN FOR PUBLIC IN 1991, established in 2006
Park typology: old

It has the emptiness of portions of the gardens. The space defines the elements around it**.**
The park has been designing as Japanese garden. This park has been renovated landscape with very artistically method, it also has participatory sensibility flourished, part of a closer tie between park programming and popular culture of Japan. According to study the park is following the Japan culture, about

native plants.

DINOSAUR GARDEN:



F3-4: showing the pathways with the help of renewable sources

Location-Jijamata Udyan,94/1, Prabhat Nagar, pimple gurav, Pimpri Chinchwad, Maharashtra 411**Built**: established in 2006,
Park typology: old
It has the emptiness of portions of the gardens. The space defines the elements around it**.**

The specialty of this park is the 40-foot Dinosaur structure that excites and invites kids! The big circular fountain welcomes the visitors as you enter the park and before you get intimidated by the life-like dinosaur, the striking water bodies and gorgeous bridges over them soothe you!

1.

DESIGN AND FORM AFFECT THE WAY PEOPLE USE THEIR PLACES:
According to the study, it is identified that both the parks had been designed in such a way that it has a slope in their periphery and flat ground in the center focal point which encourages people to sit on the ground rather than on benches, even though chairs are provided around. this central area and focal point are the flat main nodal ground.

EFFECT: children play in the central area while the people watch them seated on the elevated slopes, exactly like stadium functions. Density, diversity, and mixed usage are key elements in the creation of resilient urban development that aims to minimize carbon emissions while maximizing the utilization of available space and land. Emphasis is placed on prioritizing pedestrians, as walking is considered the preferred mode of transportation within these parks due to its significant contribution to a healthy lifestyle.

In these parks, pedestrians are given utmost priority, as walking plays a vital role in promoting a high quality of life. Furthermore, urban areas are being developed in a manner that facilitates the use of public transportation.

Placemaking is a strategy employed to foster a strong sense of belonging and identity within the community, thereby enhancing public life. In addition to preserving and improving the health of natural systems, such as climate zones and environmentally significant areas, both parks also assume responsibility for managing the impacts arising from climate change.

KAMALA NEHRU PARK:

F5: mapping of park F6:: park

Location-l Harshvardhan society, Deccan gymkhana, Pune, Maharashtra 411004
Built: 1952 renovation-2017/18
Park typology: newly renovated.
Terraced Gardens: One of the prominent architectural features of the park are its terraced gardens. The park is built on multiple levels, with each terrace showcasing a variety of plants, flowers, and trees, creating a beautiful and soothing environment.

1. Japanese Influence

SARAS BAUG:

F7: mapping of park F8: having good typology of landscape

Location- Swargate Pune, Maharashtra
Built: 1784 Renovated In 2005
Park typology: Moderate
In relation to the siddhi Vinayak temple, located in the centre of Saras Baug, the architectural design was nearly precisely symmetrical. Under the guidance of Sawai Madhavrao Peshwa and Mahadji Shinde of the Maratha confederacy, the construction of the temple began in 1755. In 1784, construction of the temple was complete with a statue of Lord Ganesh in it.

DESIGN AND FORM AFFECT THE WAY PEOPLE USE THEIR PLACES:
The architecture and design of places like Saras Baug and Kamala Nehru Park greatly influence how people

use these spaces. The layout, amenities, and overall ambiance can shape the activities and experiences of visitors. For example, in Saras Baug, the well-planned pathways, seating areas, and open spaces provide a conducive environment for people to relax, walk, and enjoy nature. The presence of a central pond and a small island accessible by a bridge creates a focal point and possibly encourages activities like feeding fish or taking boat rides. Similarly, Kamala Nehru Park's design, which includes well-manicured gardens, children's play areas, and viewpoints, can inspire various uses such as picnicking, engaging in outdoor sports, or simply lounging on open lawns. The Bal Udyan, or children's garden, within Kamala Nehru Park is specifically designed to cater to the needs of young visitors. In both parks, the architecture and design consider the comfort and convenience of visitors to enhance their overall experience. This includes the provision of seating, shade structures, and well-maintained pathways that make these places accessible and enjoyable for people of all ages.

The survey was set up after a small pilot study. Respondents were randomly selected among the visitors of the park,3 regardless of their social extraction or professional background. People approached in the park, were first informed about the survey's objective and answering procedure. Nonetheless, results provide interesting information to city planners and urban developers about the role and importance of public green space for the citizens' daily well-being and quality of life. 3. Results In total, 750 questionnaires were distributed. A relatively high percentage of questionnaires (62.3%) was returned, often accompanied by enthusiastic comments and encouraging words (i.e., a postcard, or a poem). The sample size is N = 467, prevalently constituted by females (52.7%). Age classes ranged from 15 to 65 and the mean age of the total sample is about 42 years (S.D. = 15.19). Both quantitative and qualitative analytical techniques have been used to analyze and interpret Fig. 2. Motives for nature: frequency distribution. data collected.

RENEWABLE RESOURCES ON GOING

Open spaces according visited parks:

Parks name	**Shadow portion in %**	**Open spaces in %**
Okayama friendship garden	30% (just at boundary)	70%
Kamala Nehru Park	71%	29%
Saras Baug	63%	37%
Lohiya garden	68%	32%
Dinosaur garden	33% (just at boundary)	67%

SUMMARY AND FINDINGS; The purpose of this research was to find out the design criteria for city parks, as well as investigating how these parks can play a role in enhancing urban sustainability. The objectives were to understand how urban parks are part of green infrastructure in cities, identify the direct and indirect health effects of parks with a view to examining their effect on neighbouring housing prices. Several key design criteria are identified in the study, which are decisive for urban parks to be developed sustainably.

First, it can contribute to reducing water use and promoting biodiversity by integrating indigenous plants and vegetation that are suitable for the local climate. Second, there is the potential to stimulate activity and community interaction by promoting a balanced mix of functional and passive leisure opportunities such as sports facilities, cycling routes or outdoor gathering areas. In addition, in order to make park access as simple as possible with no increasing reliance upon private cars, the research showed that it is important to incorporate safe modes of transport such as bike lanes and bus connections. The use of parks and increased connectivity with the surrounding areas are also stimulated by design of multiple entrances and well-connected pathways. As far as health is concerned, the study showed that parks are both directly and indirectly beneficial. Physical opportunities for exercise, reduced stress and improved mental health are also directly beneficial. A reduction in emissions and the heat island effect, contributing to improved air quality and lower temperatures within urban areas, are also indirect benefits. Finally, the effects on local house prices of urban parks were examined in this research. It discovered that, by virtue of their design and good maintenance, the parks have a beneficial impact on property values which makes them attractive locations for citizens who would potentially attract investments and development in neighbouring areas.

CONCLUSION: In the community, social and artistic aspects should be addressed in a sustainable design of city parks. The integration of cultural symbols, historical features and monuments in park design can reinforce the social fabric of nearby communities by creating a sense of identity, pride or kinship amongst those living there. Moreover, city parks can serve as a dynamic centre of Social Interactions, Learning and Recreational Activities by integrating space for Community Events, Gatherings and Education Programmes. Lastly, for the long-term viability of Sustainable Urban Parks it is essential to ensure that they are properly managed and maintained. The continuation of these spaces' existence and maximizing their environmental and social benefits are ensured by the application of appropriate park maintenance, waste

management and regular ecological health monitoring strategies.

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The Contribution of Inclusive Design in Foresting Social Sustainability

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Abstract:
The realization of safe, autonomous circumstances for people to realize themselves, as well as an increase in the standard of living for people, depends on "social" sustainability. Thus, to promote an egalitarian society, universal design should be used to make buildings approachable to all people, especially those who are disadvantaged in some manner, such as children, the elderly, people with disabilities, pregnant women, and the medically unfit. The goal of accessibility is to remove obstacles so that people with disabilities can use, perceive, engage with, comprehend, and navigate tools and services by defining the design vision and making it holistic by talking to people about their problems. keep up with assistive technologies and their applications to create a better user experience. Using the typical user-centered design methodologies and a material design system, which includes precise guidelines, components, and tooling, helps uncover the underlying narratives surrounding issues of disability, design, and inclusivity and how they developed. A design may be technically accessible but not necessarily used to make design inclusive. To ensure "Individual capacities"—that strongly encourage intrapersonal, interpersonal, and behavioral empowerment of disabled people, they might be employed on the ground floor of the building or provided access to lifts. Several accessibilities of laws must be implemented effectively to eliminate barriers and create opportunities for an inclusive society. Any architectural design required to accommodate people with physical impairments, such as entrances with enough space for people with physical disabilities and ramps, handrails in restrooms, corridors, doorways, and Wheelchairs. At its core, inclusive design considers the many human capacities, such as age, gender, ethnicity, and others.

Keywords:
Inclusive Design Principles; Objects Of Disability; Ethnography, Wellbeing; Social Sustainability.

Introduction

Inclusive design is more than just a concept; it's a transformative force shaping the very foundations of our society. It asserts that every individual, irrespective of age, size, or ability, is entitled to the fundamental right of human dignity. Originating from North America, the term gained traction in response to concerns about disabilities but quickly evolved into a broader perspective, encapsulating the ethos of projecting for all. Inclusive design stands alongside various approaches like "Design for All," "accessible design," "barrier-free design," and others. It's not merely a challenge; it's a philosophy deeply rooted in recognizing and celebrating individual differences. As we navigate the complexities of design, inclusive design urges us to create products, services, and environments that are not only available to the widest spectrum of people but also usable by them. The ultimate goal is to make life more accessible for everyone, fostering a society where physical surroundings, communication means, buildings, and urban environments cater to the diverse needs of the community at little or no extra cost. Far from being a mere obstacle, inclusive design becomes a harmonizing force, intertwining itself with the complexities of individual existence. It's an ever-evolving concept, addressing not only physical disabilities but encompassing a broader spectrum of considerations, including ethnicity, economic resources, education, and culture.

F1: Diversity factors in Society
Source: lbbonline.com

This philosophy takes center stage in the design project, positioning itself as a core element in the education of designers. The emphasis lies in incorporating inclusive design principles from the inception, weaving them seamlessly into the fabric of sustainable design practices. The challenge is to demonstrate how design processes can adopt a routine inclusive approach, influencing every stage of development. As we go through the European context, nearly 25% of the population encounters some form of functional limitation. Portugal, with more than a million individuals facing various disabilities, grapples with the imperative of making its physical environment more inclusive. It's not merely about dismantling barriers but instilling a mindset that values equal opportunities for participation.

The Lisbon Faculty of Architecture (FA) emerges as a vibrant hub where inclusive design transcends theoretical discourse to become a tangible force driving research and education. The Design Innovation

Laboratory (LID) at FA serves as a nucleus for ongoing projects such as the "Observatory in Inclusive Design," "Evaluation of the Accessibility and Usability Conditions of ATM Machines," and "Design Ergonomic Project." These initiatives exemplify a commitment to instilling inclusive design not just in theory but in the practical realms of design projects and education. The pursuit of inclusive design, therefore, extends beyond the realm of accessibility. It becomes a catalyst for societal change, aiming not only to reduce physical barriers but to embed inclusivity in the very foundations of our choices regarding spaces, environments, objects, and information design. This endeavor is not just a quest for accessibility; it is a journey toward sustainability, social responsibility, and a profound respect for human rights.

1. History: From Exclusion to Social Participation

In the evolution of architectural design, the concept of the "mythic average user" has significantly shaped the structures we inhabit. Architects traditionally prioritized considerations such as style, form, materials, structure, and cost over the diverse needs of the bodies and minds meant to occupy these spaces. However, examining specific elements like doorways, windows, toilets, or desks within a building unveils the implicit assumptions about the bodies intended to use them.

The notion of the "mythic average norm" can be traced back to historical perspectives on idealized bodies. In the 1st century BC, Roman architect Vitruvius prescribed an idealized body as the template for beautiful architecture, emphasizing symmetrical harmony and proportions. This idealized body became a standard for classical architecture, influencing not just aesthetic considerations but also defining the authoritative architects who mastered the knowledge of human life and embodiment.

As architectural practices evolved, the Vitruvian Man's status as a scientific object emerged during the Renaissance. Artists like Leonardo da Vinci depicted this figure, emphasizing idealized proportions. However, in the 19th century, with the rise of positivist standards of knowledge, architectural discourse distanced itself from these classical depictions, discrediting them as myth and illusion. Yet, the Vitruvian Man's representations found new life in anthropometry, a practice that measured human populations with calipers and rulers, claiming to produce objective standards.

This scientific turn in the 19th century laid the groundwork for the "architecture of exclusion," where design decisions were often indifferent or negligent regarding accessibility. Discrimination persisted, exemplified by racially segregated facilities in the United States and apartheid policies in South Africa. The architecture of dependence followed as institutions developed to address accessibility issues, albeit often in a separate but equal manner.

The disability rights movement, starting in the late 1960s, marked a crucial shift. Laws were enacted globally to prohibit discrimination based on disability, initiating a phase of the architecture of independence. However, early attempts at accessibility were often haphazard, leading to unintended consequences. Symbolic representations like the International Symbol of Accessibility (ISA) aimed to denote accessible facilities but faced reinterpretation and criticism, symbolizing passivity rather than empowerment. In eliminating discrimination, well-intentioned efforts sometimes result in absurd situations. Legal mandates, like reserving picnic areas for people with disabilities, highlighted the challenges of balancing inclusivity and unintended privilege. The journey towards social participation and equality in opportunity through universal design is the emerging paradigm in many societies today.

This evolution, however, is not without challenges. Barriers persist in both high-income and low-income settings, and social integration and understanding of disability are ongoing struggles. As societies strive for equal opportunity, unintended consequences of accessibility measures, such as elevators in subway stations benefiting various groups, become apparent.

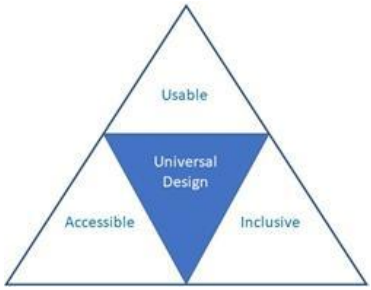
The trajectory of architectural development reflects broader societal perspectives on disability. The shift from exclusion to independence is a positive trend, but challenges remain in achieving true social participation. The current goal is the "architecture of social participation," emphasizing equality in opportunity through universal design. As we navigate this evolving landscape, addressing the unintended consequences of accessibility measures becomes crucial for fostering inclusivity without reinforcing dependency or creating unnecessary barriers.

2. Social Sustainability through Inclusive Design

Universal design (UD) is the process of creating places and products that can be utilised by everyone without the need for special design or adaptation, (Ronald L. Mace, Centre for Universal Design, United States, 1991). Whatever one's ability level, it seeks to optimise accessibility for everybody. (**figure2**)

The United Nations established the concept of sustainable development in 1987, and this idea is in line with it. Meets current demands without jeopardising the ability of future generations to fulfill their own needs—a principle known as sustainable development.

Universal design is not just a design philosophy; it's a national strategy. In the United States, the Ministry of Children, Equality, and Social Inclusion oversees the government's policies in this field through the Action Plan for Universal Design and Increased Accessibility (2009-2013).



F2: Key Characteristics of UD
Source: Burgstahler 2021, University of Washington, DO-IT

Social sustainable development encompasses various factors like basic human needs, equity, social accountability, empowerment, local self-reliance, participation, inclusion, accessibility, appropriate technology, protection of mental and physical health, community development, fair treatment of stakeholders, access to social resources, and provision of essential services. (**figure3**)

The universal design significantly contributes to social sustainability. It plays a crucial role in creating secure and autonomous conditions while enhancing the quality of human life. By actively involving everyone, including children, the elderly, differently-abled individuals, pregnant women, and the medically unfit, universal design becomes a catalyst for fostering equality and making buildings approachable for all. In essence, universal design becomes a cornerstone in achieving "social" sustainability, making a positive impact on society's overall well-being.

F3: Design and User Experience
Source: web.dev/learn/accessibility/design-ux

3. From Universal Design Philosophy to Practical Implementation

Why Universal Design Matters:

Mastering Everyday Life: The goal is to ensure that everyone can navigate and excel in their daily activities effortlessly.

1. **Gender Equality and Non-Discrimination:** Universal design seeks to break barriers and create environments where gender disparities and discrimination are eliminated.
2. **Equal Opportunities:** By promoting universal design, we pave the way for equal opportunities for everyone, irrespective of abilities or backgrounds.
3. **Active Participation in Society:** Universal design encourages individuals to actively engage in societal activities, fostering a sense of belonging.

How Universal Design is Applied:

1. **Public Action Plans and Legislation:** Creating a framework through public action plans and legislation establishes a foundation for widespread adoption.
2. **Profitable Market:** Universal design is not just a philosophy; it's a lucrative market. Businesses benefit by embracing inclusivity.
3. **Developing Solutions:** Crafting physical, digital, and organizational solutions that align with universal design principles.

Design Actions for Inclusive Spaces:

1. **End-User Participation:** Involving end-users in the design process ensures a higher quality of outcomes.
2. **Understanding User Requirements:** Discovering and comprehending the needs and wishes of users, considering context and tasks.
3. **Applying Standards and Guidelines:** Using and transforming standards, guidelines, and checklists to meet inclusivity criteria.
4. **Testing and Evaluation:** Regular testing and evaluation involving users throughout the design process for continual improvement.

Classification of Human Abilities:

1. **Sensory Abilities:** Covering sight, hearing, touch, taste, smell, and balance.
2. **Physical Abilities:** Encompassing speech, dexterity, manipulation, mobility strength, and endurance.
3. **Cognitive Abilities**: Including intellect, memory, language, and literacy.

Elements in an Inclusive Design Process:

1. **Specifying Context:** Defining the usage context is vital for understanding user requirements and ensuring usability.

2. **Discovering User Needs:** Identifying and translating user wants and needs, adapting standards into requirements.
3. **Evaluation and Testing:** Regularly testing prototypes and solutions, modifying them based on user feedback, and conforming to standards.

Universal design is not just a theoretical concept; it's a practical, iterative process aimed at creating environments that truly cater to the diverse needs of individuals.

Human Factors and Ergonomics

Universal Design stands as a close ally to Human Factors and Ergonomics (HFE), embarking on a shared mission to consider the capabilities and limitations of users in the development of products and built environments. The underlying user models in different domains differ, despite their same overall objective, which defines what makes Universal Design unique.

This conventional approach predominantly tailors design for the vast majority, typically covering 95% of the target population. Unfortunately, this leaves a considerable portion of the population excluded, relying on assistive devices to bridge the accessibility gap. Universal Design, on the other hand, introduces a paradigm shift by adopting a User Pyramid model. This pyramid encapsulates a broader

spectrum, acknowledging users with varying abilities. At the base lie able-bodied individuals and the elderly with minor disabilities. Moving upwards, the middle section accommodates those with reduced strength and mobility, including age-related impairments. Finally, the apex caters to individuals with severe disabilities, such as those in wheelchairs or with limited strength and mobility in their hands and arms.

The essence of Universal Design resides in its dedication to designing mass-produced products or environments that can be navigated effectively without external assistance, ensuring inclusivity for individuals with functional limitations. Unlike traditional HFE approaches, Universal Design extends its reach beyond the majority, striving to embrace a more diverse user population. This iterative process continually widens the target user demographic with each reiteration of product or service design.

Over the past two decades, the theory and practice of Universal Design have undergone substantial evolution. The technological revolution, particularly in Information Technology, has been a catalyst for transformative shifts in Human Factors and Ergonomics. This technological wave has not only redefined how we approach design but has also prompted a reevaluation of fundamental concepts such as Disability, Assistive Technology, and Universal Design.

Examining the landscape of Universal Design, we identify two notable shifting paradigms that mark its evolutionary journey. These paradigms reflect the dynamism in the field and the responses to evolving societal needs:

1. **Expanding Accessibility Horizons:** Universal Design, as a response to exclusionary practices, has embarked on a continual journey to broaden its accessibility horizons. Each iteration in design serves as an opportunity to encompass a more diverse user base, challenging the limitations imposed by traditional models. (Üstün, T.B. (1999).

2. **Technological Reshaping:** The advent of Information Technology has propelled Universal Design into uncharted territory, demanding a reassessment of its core definitions and principles. This technological surge not only alters how we interact with the built environment but also prompts a reconsideration of our understanding of disabilities and the role of assistive technology. In essence, Universal Design is not static; it is a dynamic force responding to the evolving needs of a diverse population.

Cognitive and Physical Dependency

It is imperative to explore the pragmatic aspects of cognitive and physical dependency in the process of creating inclusive environments. Designers may develop spaces that accommodate a varied range of abilities and ensure a sense of belonging for all by acknowledging the challenges presented by these elements.

Cognitive Capabilities:

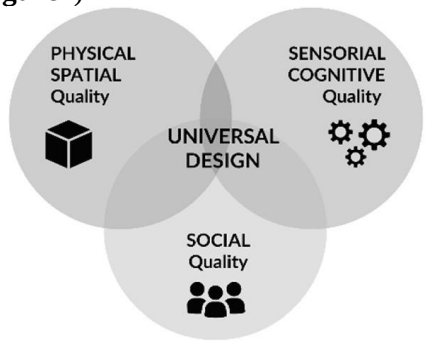
Our mental abilities are key to functioning independently From interpreting sensory information to making decisions, these cognitive functions naturally decline with age, affecting an individual's response to novel or complex situations. Designing with cognition in mind involves understanding the practical implications of mental processes, and distinguishing stable abilities from those susceptible to age-related changes. Essential cognitive functions, such as attention and concentration, undergo shifts as we age. Sustaining attention and multitasking become more challenging, requiring environments that account for these changes. The aging brain experiences physiological shifts, including the loss of brain cells and reduced connections. However, the brain's adaptability, even in later stages of life, reinforces the importance of engaging mental faculties actively.

Human Differences and Capabilities:

Human capabilities vary, shaped by genetic factors and

complex interactions with social, economic, and experiential elements. Multiple intelligence, as conceptualized by Howard Gardner, identifies various cognitive strengths, emphasizing the need to appreciate and nurture diverse abilities. In the design context, human differences are evident in how individuals interact with interior spaces. Gardner's multiple intelligences, including verbal, visual, and interpersonal strengths, underscore the importance of tailoring designs to accommodate these varied cognitive abilities. Interior spaces, when aligned with cognitive capabilities, significantly contribute to the well-being, comfort, and efficient functioning of individuals.

Physical Dependency:
Physical capabilities are equally critical to an individual's independence. Inclusive design extends beyond cognition to address physical dependencies. Considerations such as ramps, elevators, wider doorways, and ergonomic designs facilitate mobility and accessibility for individuals with varying physical abilities. Designing with physical dependency in mind ensures compatibility with assistive devices and creates environments that empower individuals with diverse needs. (**figure4**)



F4: Assessing Building Usability with Universal Design. Source: SpringerLink

Case Study-01: Enabling Village, Singapore
In 2015, Singapore witnessed a transformative project as the old Bukit Merah Vocational Institute evolved into the Enabling Village, a testament to the principles of Universal Design. Designed by WOHA, this innovative space goes beyond physical accessibility to create a community hub that seamlessly integrates individuals with disabilities into daily life. The Enabling Village prioritizes inclusive accessibility, ensuring wheelchair-friendly pathways and universally accessible restrooms and public spaces. (**Figure 5**) Thoughtful facilities include induction loops in event spaces for those with hearing aids and braille maps for individuals with visual impairments. Elements like ATMs are designed with braille labels and earphone ports, enhancing usability for diverse users.

F5: Use of Handrails and Ramps
Source: Edward Hendricks

Going further, the Enabling Village houses a center for innovators dedicated to testing and developing assistive technology. Fully soundproof and lightproof spaces enable inventors to refine their products, contributing to advancements in accessibility. (**Figure 6**) The project extends its impact through job creation, aiming to offer employment opportunities for differently-abled community members and actively contribute to social and economic sustainability. (**Figure 7**)

The Masterplan envisions the Enabling Village not just as a physical space but as a revitalized heartland connected to the neighborhood's pedestrian network. WOHA's comprehensive design scope covers architecture, interior design, signage, lighting, art, and landscaping, creating a harmonious blend of existing and new structures.

F6: Artfully Designed Seating Areas Along Corridors, Accommodating Inclusivity with Stylish Lighting Displays. Source: Edward Hendricks

Championing sustainability, the Enabling Village repurposes existing structures and integrates landscaping, water gardens, and art to attract biodiversity. Verandahs and meeting spaces extend into nature, creating outdoor areas that bring people closer to the environment. the Enabling Village is more than architectural innovation; it's a living example of how design can break down barriers and foster a sense of belonging for everyone. This project is an outstanding example of inclusivity, adhering to the principles of Universal Design, and supporting the social sustainability of Singapore's varied community.

F7: Wide, accessible spaces with well-utilized handrails. Source: Edward Hendricks

Case Study-02: A perceptual survey of Orchha Temples, Madhya Pradesh, India

Pilgrimages are meaningful journeys to sacred places for people's beliefs. India has many pilgrimage sites, attracting thousands of devotees from different places. These pilgrims vary in age, abilities, backgrounds, and where they live. Many elderly people and those with disabilities visit these sites, facing challenges along the way. Despite being a significant portion of visitors, their needs are often ignored in planning, making their journey difficult.

Recently, pilgrimage sites have seen development, but it mostly focuses on making them look better. There's little effort to make them accessible to everyone, improving safety and comfort for vulnerable groups.
This perceptional survey conducted on the Orchha temples sheds light on the absence of inclusive design elements and further explores potential solutions in the concluding segment.

F8: Entrance of Ram Raja Temple, Orchha
Source: Trodly.com

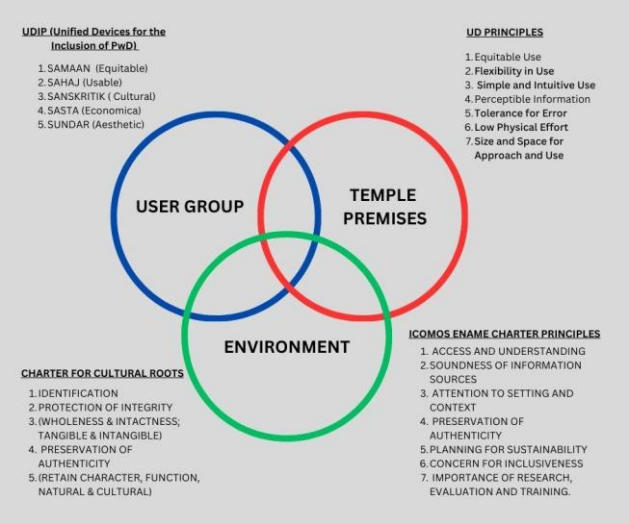
HISTORICAL CONTEXT

Orchha, established in 1531 by Rudra Pratap Singh, a Bundela leader, features notable structures like the Orchha Fort he built. The Chaturbhuj Temple, attributed to Queen Ganesh Kunwar, and Raj Mandir, constructed by Raja Madhukar Shah, are part of its legacy. However, Mughal forces led by Prince Aurangzeb seized Orchha in October 1635. Orchha also boasts landmarks like the Ram Raja Temple and Jahangir Mahal, along with various cenotaphs and temples. Adding to its cultural richness is Radio Bundelkhand, a community station airing in the Bundeli language since its inception in 2008.

ACCESSIBILITY ASSESSMENT

Physical Barriers	Intellectual Barriers
1. Modernization can be observed, but accessibility for differently abled people is lacking.	**1.** Darshan (the sight of deity) is difficult due to crowds, with no special place designated for differently abled people to view the idol.
2. Separate entry points for wheelchairs are absent.	**2.** No parking provisions for wheelchairs.
3. Uneven plains and inconsistent staircase risers make navigation challenging.	**3.** Lack of directions to the temple and demarcation of parking areas.
4. Lack of railings along staircases further impedes mobility.	**4.** Absence of information desks or receptions at the entrance.
5. No parking provisions are available for wheelchairs.	**5.** Insufficient signage or braille boards on the campus.
6. Level differences within the campus pose additional obstacles.	**6.** Lack of recreational spaces.
7. Inappropriate design details like railing design, flooring material, etc., are observed.	
8. Confusing circulation, meandering staircases in different directions, and uneven widths make physical access difficult.	

SOLUTIONS FOR IMPLEMENTATION



F9: Sustainable Model

1. **Sensory Bollards and Wrist Bands:**
   - Bollards with tactile guidance and directional cues placed regularly.
   - Entrance wristbands activated by sensors.
   - Neon lighting on bollards aids visual access, suitable for wheelchair users.
2. **Railing Details:**
   - Smooth handrails with tactile changes provided.
   - Handrails installed at two levels (450mm and 900mm) for universal use.
3. **Street Lighting and Signage:**

- Innovative street lighting with multilingual signage and waste disposal facilities.
- Solar panels integrated into street lights.
- Expandable frames for temporary rain coverage.

4. **Inclusive Bell Panel:**
   - Temple bell accessibility improved with different-sized bells at varied heights.
   - Panels of bells installed along temple aisles for universal access.
5. **Drinking Water Facility:**
   - Kiosks designed for inclusive use by all, including wheelchair users and children.
6. **Multilevel Seating:**
   - Universal seating areas for relaxation and recreation.
   - Information panels integrated for intellectual access.
   - Bird feeders providing sound cues for visually impaired users.

ENSURING SUSTAINABLE PILGRIMAGE SITES

- Integration of new and existing elements into the site.
- Full accessibility ensured from entrance to built-up areas.
- Retention of architectural value through material and architectural features.
- Preservation of natural value by retaining existing flora and using local resources.
- Intangible qualities preserved by accommodating existing activities and elements.
- Cultural and religious significance maintained while accommodating existing activities.

Breaking Down Barriers: Navigating Challenges in Universal Design

Universal design, heralded for its potential to cater to the needs of individuals facing age-related declines, is not without its share of hurdles. While the concept holds immense promise, its implementation grapples with several challenges that demand attention and innovative solutions.

1. Education Gap in Design Professions:

A significant challenge lies in the dearth of education provided to engineers, architects, and environmental planners regarding the significance and application of universal design. The lack of a standardized educational framework contributes to the ambiguity surrounding its definitions and principles. Bridging this education gap is paramount to fostering a comprehensive understanding of universal design and its potential benefits.

2. Theory vs. Practice Dilemma:

Universal design faces limitations as it contends with a reality where established norms and codes take precedence over theoretical frameworks. The challenge lies in moving beyond theoretical foundations and positioning universal design as a "best practice" that surpasses mandated codes and guidelines. Currently, its principles often take a back seat in decision-making processes. (H.H. Danso,2012)

3. Understanding Diverse User Needs:

Incorporating designs that cater to the varied needs of users with diverse abilities poses a significant challenge. Architects, even with a grasp of accessible design, may struggle to interpret the barriers experienced by end-users. The disconnect arises when decisions regarding accessible design lack substantial input from those directly affected. This is particularly evident in the case of older adults, where architects may not fully comprehend the barriers within the built environment that impact this demographic.

4. Cost Considerations and Client Priorities:

The discrepancy in perceptions of costs associated with universal design creates another hurdle. While academics suggest that it can be implemented with minimal additional costs, the practicality of implementing accessible and universal designs reveals the need for more square footage, subsequently increasing construction costs. Moreover, the primary determinant in incorporating universal design remains the client's priorities. If the client does not perceive it as crucial, and local building codes do not mandate it, architects find themselves constrained in implementing these principles.

5. Multidimensional Solutions for the Future:

Overcoming these challenges demands a multifaceted approach. To pave the way for a more inclusive future in architecture and environmental planning, professionals can consider several strategies:

5.1Educational Reforms: Integrate universal design into educational curricula for designers, emphasizing its importance in real-world applications.

5.2User-Centric Design: Foster communication with older adults and individuals with disabilities during the design process. This ensures a comprehensive understanding of the diversified needs of the entire population.

5.3Collaborative Initiatives: Encourage collaboration among professionals to elevate universal design to a "best practice" guideline, surpassing minimal code requirements.

5.4Cost-Effective Innovation: Invest in research and development to discover more cost-effective ways to implement universal design. Increasing affordability

can enhance client willingness to embrace these principles.

6. Future Research and Transformative Vision:

While the theory and literature surrounding universal design show promise, there is a critical need for more empirical evidence. Rigorous research, including randomized controlled trials, can substantiate the effectiveness of specific universal design options. Through dedicated research and knowledge translation efforts, universally designed environments can transition from promising concepts to the norm and code of practice for architects and design professionals.

7Embracing a Universal Vision:

As a society, there is an urgent call to embrace the philosophy of universal design. Shifting individual attitudes towards perceiving the population as a whole, where everyone can prosper in the environment regardless of ability or age, is a collective responsibility. By addressing these challenges head-on and implementing innovative solutions, we can break down barriers and create a more inclusive and accessible built environment for all.

Conclusion

"The essence of universal design lies in its ability to create beauty and mediate extremes without destroying differences in places, experiences, and things**"**. -Bill Stumpf and Don Chadwick, Designers. The need for everyone to access and use interactive systems is clear, but there are different ways to make this happen. This paper shows how different approaches to accessibility aim to provide effective opportunities for all users, no matter their challenges. While the variety of approaches can be confusing, it also highlights the need for more research to establish common ground. This paper explains the importance of working together to understand accessibility better. A clear definition helps us talk about it, put ideas into action, and develop new methods.

Universal Design is vital for making society sustainable and inclusive. This paper demonstrates how it can be applied in public spaces like pilgrimage sites, offering new ideas and solutions. To overcome challenges like cost, we need teamwork and creative thinking. Universal Design has evolved from focusing on disabilities to including everyone. It's important to show that it works and should be a part of our everyday lives. Spaces should be more than just functional; they should be exciting and welcoming to everyone. It's up to future generations to make sure our environment is inclusive and accessible to all. This means breaking down barriers and embracing diversity. Achieving true inclusivity requires us all to work together for harmony between people and their surroundings.

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Author Profile

Deepika Shukla, a young and passionate learner, explores the intricate interplay between architecture, human relations, and sustainability. Believing in the interconnectedness of all aspects, she sees nature expressing itself in diverse ways. Deepika perceives architecture as a transformative force, driving positive change and envisioning a future evolution for a better civilization. With a holistic approach, she delves into the complexity of architecture while embracing the profound connections that bind everything together

Community Engagement in Sustainable Development

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Abstract:
Indigenous communities throughout the world use their indigenous knowledge systems to make substantial contributions to environmental sustainability. These societies have established behaviors that support biodiversity protection, sustainable resource management, and resilience to environmental changes based on centuries of experience and strong connections with their environments.
In earlier times humans interacted with the surroundings based on a comprehensive understanding of nature with both sacred and secular underpinnings. Thus humans and nature evolved through processes of cultural synthesis and specific practices within our complex and diverse culture. The fundamental understanding of geography and the ascribed associations to its natural features led to the integration of man with place to shape a cohesive landscape. This rich tradition of conservation of our natural assets seems to dissipate due to a limited understanding of our official systems for effective identification and safeguarding of our cultural resources, associations, and practices.
Indigenous populations are becoming more and more vulnerable as a result of modern issues including urbanization, industrialization, and infrastructural development. Their marginalization and relocation disrupt not only their lifestyles but also the delicate balance they preserve with their natural environments. This is demonstrated by the encroachment on traditional lands, which causes the cultural heritage to erode, biodiversity to disappear, and sustainable practices to be disrupted. The effects of significant infrastructure developments on coastal fishing villages are one such example. The livelihoods and environmental stewardship of these people are threatened by development projects that modify coastal ecosystems and restrict access to traditional fishing areas.
Thus, it is essential to safeguard indigenous knowledge and promote community involvement in the face of these difficulties. It is crucial to have policies that uphold the rights of indigenous peoples and allow them to participate in decision-making. Recognizing the complex relationship between conventional ecological knowledge and environmental preservation is crucial for effectively managing the complexities of current issues while conserving ecological integrity and cultural diversity.

Keywords:
Indigenous Knowledge Systems, Environmental Sustainability, Urbanization, Marginalization.

Introduction

Indigenous communities around the world use their centuries-old indigenous knowledge systems to make major contributions to environmental sustainability. These communities, which have a strong connection to the natural world, engage in practices that promote biodiversity, sustainable resource management, and adaptability to changing environmental conditions. However, their cultural legacy, biodiversity, and sustainable practices are in danger due to contemporary issues including urbanization, industrialization, and infrastructure development.

Both environmental stewardship and livelihoods are threatened by the encroachment of traditional lands. Indigenous knowledge is frequently not adequately protected by current official systems, which undermines their valuable conservation traditions. Understanding the intricate connection between traditional ecological knowledge and environmental preservation is essential to addressing these issues.

Importance of Indigenous community and Indigenous knowledge systems

Preservation of Cultural Heritage: Rich cultural traditions, languages, and customs that have developed over centuries are preserved among indigenous groups. Indigenous knowledge systems are essential for maintaining cultural heritage because they transmit information from one generation to the next.

Environmental Sustainability: A thorough understanding of ecosystems, biodiversity, and sustainable resource management is a component of indigenous knowledge. Using their knowledge to preserve and safeguard natural resources, indigenous cultures frequently act as environmental stewards. Adaptation to Local Environment: Communities are able to adapt and flourish in a variety of circumstances because indigenous knowledge is intrinsically linked to particular geographic areas.Sustainable practices that are tailored to the particular opportunities and difficulties of their environment are made possible by this localized expertise.

Biodiversity conservation: Given that all living things are interrelated, indigenous tribes frequently take a holistic approach to biodiversity conservation. By protecting biodiversity, traditional ecological knowledge helps to preserve the delicate balance that exists throughout ecosystems. Resilience to Environmental Changes: Indigenous knowledge systems are flexible, developed across many generations in response to changes in the environment. By utilizing their traditional wisdom, indigenous cultures show resilience in the face of environmental difficulties, including climate change.

Aim:
This research aims to assess the impact of urban development on indigenous communities and promote sustainable practices, safeguarding indigenous knowledge amidst challenges posed by urbanization & infrastructural projects.

Objectives:
1. Evaluate the effects of industrialization and urbanization with an emphasis on environmental stewardship
2. Identify the challenges posed by infrastructure projects that have an impact on native populations.
3. Develop strategies to protect indigenous knowledge, encourage participation in the community, advocate for policy changes, and improve environmental sustainability.

Literature Review

It entails actively participating in decision-making procedures to guarantee that the various needs and viewpoints of community members are taken into account. When it comes to addressing the environmental, social, and economic issues, this involvement is very important.

3.1 **Inclusive Decision-Making:** Community involvement guarantees that local communities' perspectives, concerns, and goals are taken into account while making development decisions. Inclusionary practices lead to more just and efficient solutions.

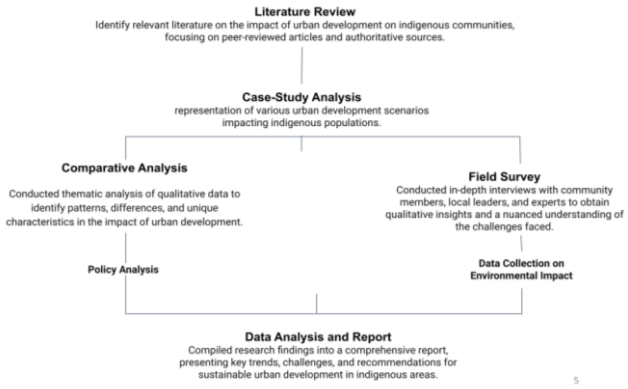
3.2 **Local Wisdom and Knowledge:** Communities have important traditional knowledge and skills that are vital to sustainable development. Interacting with them makes it easier to incorporate this knowledge into projects, which improves their sustainability over time.

3.3 **Social Cohesion:** Strong social ties are conducive to sustainable growth. The success of any development project depends on social cohesion, which is reinforced by community participation, which creates a sense of community and shared responsibility.

3.4 **Customized Solutions:** Communities differ in their requirements and diversity. By interacting with them, development plans can be tailored to their needs, guaranteeing that interventions are culturally and context-appropriate.

3.5 **Environmental Stewardship:** Taking the environment into account is crucial to sustainable growth. Communities that are actively involved tend to take better care of the environment, encouraging actions that preserve biodiversity and ecosystems.

1. **Methodology**



Case Study

Case of Fishing Community Bhopal

Bhoipura fishing community which settled on the edge of lower lake in the 17 th century during the rule of Hayyat Muhammad Khan is an outstanding example that displays centuries of interaction between people and their environment in a very specific and productive way, optimizing the common resources to generate huge incomes that is a significant part of the local economy.

F1: Location map- Fishing Community, Bhopal

The livelihood of this community is at stake because of increase in contamination of water by the activities such as idol immersion, dumping of religious offerings into the lake leading to dissolving of paints, addition of clay and non-biodegradable material to water; washing of clothes by the dhobis on the ghats leading to addition of detergents to water, open drains directly let into the lake leading to algal blooms which ultimately causes a threat to the aquatic life. Its vulnerability in face of increased water contamination has prompted protection measures to protect the age-old community and its threatened livelihood.

Case of Agrarian Community, Satara

The community is indigenous to this area as the community has been living in this area for many years. The community knows the importance of the surrounding natural settings and has a deep knowledge in terms of traditional cultivation techniques, the homestead gardens, and the ways to protect

surroundings. In the past few years due to the influx of tourists, and due to exceeding demand for resources, development is seen by clearing the parts of forest which are the hotspots of biodiversity. Many wild animals can be seen in the human inhabited areas because of the loss of these dense habitats. These animals are also responsible for destruction of farmlands which is the result of human animal conflict. Thus, these losses further led to insufficient income for the families to sustain. As a result the newer generation from these communities have started migrating to newer cities in search of employment opportunities. The traditional knowledge of the medicinal qualities of plants found in the area, the techniques of agriculture, and the importance of surrounding ecology is not efficiently transferred to next generations. This is leading to cultural loss. The agricultural lands are converted to non- agriculture where new structures which do not integrate with the surroundings are built on these lands.

F2: Location map- Agrarian Community, Satara

Conclusion

In conclusion, this research highlights the critical implications of urban development on indigenous communities globally. The vulnerabilities stemming from urbanization, industrialization, and infrastructural development not only threaten the cultural heritage and traditional practices of these communities but also disrupt the delicate ecological balance they have historically maintained. The overarching message is a call for inclusive and culturally sensitive urban development policies that integrate indigenous knowledge systems. Recognizing the importance of preserving indigenous knowledge and promoting community involvement is not just an ethical imperative but a pragmatic necessity for achieving sustainable development. As urbanization continues worldwide, lessons drawn from the challenges faced by indigenous communities provide valuable insights for fostering resilient, inclusive, and environmentally conscious development practices on a global scale.

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Author Profile

Sakshi Mahadik has received B.arch Degree from BKPS College of Architecture from Savitribai Phule Pune University in 2019 and M.Arch in Urban Design from Kamla Raheja Vidyanidhi Institute of Architecture from Mumbai University in 2021. She has topped her Final Year Thesis for Masters and her work was displayed at Urban dialogue an Exhibition Initiative by a group of Colleges around India to highlight exemplary design projects. Associated with the Bharati Vidyapeeth (Deemed to be University) College of Architecture for the last 1 year as core faculty. Furthermore, Sakshi is actively engaged in expanding her research interests and making significant contributions to the field of architecture and urban design through her ongoing doctoral studies.

Swapnali Sutar received her Bachelors in Architecture degree from Bharati Vidyapeeth Deemed to be University College of Architecture in 2017. Later she completed her Master's degree in Urban Design in 2019 from Savitribai Phule Pune University. She has been associated with the Bharati Vidyapeeth Deemed to be university College of Architecture for 4 years as core faculty. She got an opportunity to prepare policy guidelines for self-sustainable villages, a case study of Rajuri &Belhe, Pune District under MoPR which was recognized by both National and Local Agencies. Continuing her academic journey, Swapnali is currently pursuing her Ph.D. at Bharati Vidyapeeth Pune, furthering her research interests and contributions to the field of architecture and urban design.

Algae: The Next Biofuel

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Abstract: '
With new age comes new technology'. The demand for new technologies is growing with the minute, but the need for greener technologies is growing with the second. To satisfy the need & demand for energy, the industries have come up with many technologies, one of them is the solar panels for solar based generated water heaters or to produce electricity.
The process of producing and disposing of the solar panels is a difficult process; the path from cradle to grave emits a substantial amount of hazardous gases, especially the disposing process of the panels. Many studies have been carried out regarding the disposal methods of the solar panels and alternate solutions have been studied, but most of the conclusions have led to the disposal process panels generating high emissions of hazardous gases including carbon emission.
The alternative to conventional solar is replacing the base material with more eco-friendly material & that is algae. These algae based solar panels are called Bio photovoltaic panels. The definition of BPV – Biological solar cells that generate electricity from the photosynthesis activity of living microorganisms such as ALGAE.
This following research paper will cover the procedure and technical aspects of the BPV including the process of production on algae. Cradle to grave process will be laid down step wise to give a clear path on the whole procedure.

Keywords:
Solar Panels, Technologies, Algae, Sustainability, Biofuel.

Introduction

The demand for energy is increasing around the globe in all sectors & this is leading to a crisis. It is rightly said that need is the mother of all innovations and over the years industry has witnessed a noticeable evolution in the technological advancements to fulfill the demands. Most of the energy generating resources have been proven to release greenhouse gases and harmful gases that damage the environment. Many innovations are being made all around the globe for bringing in cleaner technologies generating cleaner energies, which won't harm the environment in any way. One such cleaner technology is **'BIO-PHOTOVOLTAIC CELLS'**

Bio-photovoltaic cells are an alternative to conventional photovoltaic panels. The base or the core material is algae (microalgae & cyanobacteria). Algae is found abundantly in nature; the core process i.e photosynthesis of the plant is used in the generation of electricity. The following paper is a second-hand study. Conducting this experiment and preparation of the base field will need a lot of time, space and the most vital driving force of the economy. Therefore, this research will help boost the use and search for green technology and green materials.

1. What is Photosynthesis?

Photosynthesis is a process that uses sunlight to break down CO2 present in nature to break down further and act as a food source to the plants. This process is used by plants, algae and other organisms to convert chemical energy into electrical energy.

$6CO_2 + 12H_2O$ + Photons → $C_6H_{12}O_6 + 6O_2 + 6H_2Oz$

The stages of photosynthesis are well defined in the given image, but the whole process of generating electricity or current through the process of photosynthesis is unimaginable.

2. Types of Algae Used for Production of Electricity

3 Basic Information

Cyanobacteria and Eukaryotic algae are the two types of algae studied for the process of making BPV. Similar to microbial fuel cells, BPV has the advantages of self-assembly, self-repair and natural degradation because photosynthesis organisms can reproduce themselves.

CO2 + H2O + nutrients → O2 + Biomass + Waste Heat

A). Cyanobacteria – It is the most studied algae in the research of BPV. As a single-celled prokaryote, cyanobacteria have relatively simple cell membrane arrangement, which is conducive to electron output, and contains chlorophyll a, lutein, carotene, phycobilirubicin and other pigments, which has a good light adaptation mechanism. The nutritional

requirements of cyanobacteria are simple, light, water, carbon dioxide and inorganic salts.

B). Eukaryotic Algae – A collection of extremely diverse, nonrelated organisms that perform photosynthesis in plastids, permanent organelles of green, brown, or bluish colors derived from endosymbiosis. They have increased light absorption on a wider spectrum range and is also more efficient.

3.1 Production process

Microalgae are capable of growing rapidly. Their high photosynthesis efficiency coupled with the ability to accumulate a large amount of bioproducts within their cells make them a suitable candidate to serve as industrial raw material. Besides, cultivation of microalgae does not require fertile land, a large quantity of freshwater, and herbicides and pesticides when compared to the other crops and thus will not be competing for resources. Furthermore, cultivation of microalgae can even be performed using wastewater such as domestic sewage water and palm oil milling effluents which can assist in bioremediation of wastewater. Apart from wastewater treatment, cultivation of microalgae can also help with reduction of atmospheric carbon dioxide through photosynthesis, effectively contributing to the efforts of tackling greenhouse effect and global warming. Despite the benefits of microalgae cultivation, its developments are still plagued with various problems. For example, the low biomass production and the small size of cells when they are cultured in liquid medium render the harvesting process of microalgae very costly. An ideal microalgae culturing system should possess the characteristics, including: (1) adequate light source, (2) effective transfer of material across liquid-gas barrier, (3) simple operation procedure, (4) minimal contamination rate, (5) cheap overall building and production cost, and (6) high land efficiency.

3. About Bio-Photovoltaic Systems

4.1 Basic Information

Bio-photovoltaics (BPV) is light dependent production of external electrical current (extracellular electron transfer, or EET) by photosynthesis microorganisms. The current can be harvested by an anode in a suitable bio-electrochemical systems and used to power small electronic devices. BPV systems usually utilize bacteria that carry out oxygen-producing photosynthesis (cyanobacteria) or unicellular eukaryotic algae (organisms whose photosynthesis takes place in a discrete subcellular compartment, the chloroplast).

4.2 Design Specifications

BPV device comprises of two electrode systems. The photosynthetic cells are associated with the anode, where they form a layer that transfer electrons to electrode without need for addition of any redox mediator. The cathode uses the electrons generated at the anode to reduce oxygen, usually with platinum baste catalyst. Three electrode systems incorporate, in addition, a reference electrode, allowing the potential of the working electrode to be measured or manipulated with reference to the standard electrode. A three-electrode system allows analytical electrochemical measurements to be made that are possible, or are less reliable, with a two-electrode system. Two electrode systems can provide information on the total power output from BPV device and parameters that affect it. Two-electrode systems are likely to be more desirable, being simpler.

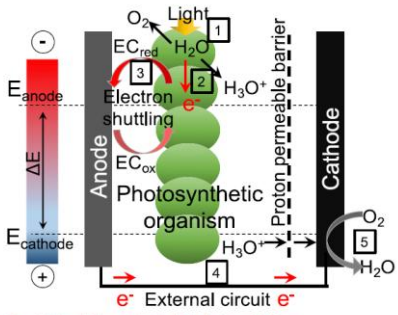

Figure 1. Schematic Diagram (Not to Scale) of a Biophotovoltaic System
Photosynthetic microorganisms (green ovals) absorb light energy (1) and oxidize water (2), liberating molecular oxygen and electrons. The latter would typically be used for carbon dioxide fixation, but in a BPV, some are passed (in some instances via an electron carrier, EC) to the anode (3). The electrons then pass through an external circuit (4) to the cathode, driven by the difference in redox potential between the electrodes, where they recombine with protons and oxygen (5). In some instances, the anode and cathode are separated by a proton-permeable membrane. In a microbial fuel cell, the electrons are generated by heterotrophic metabolism of organic matter, rather than light-driven water oxidation.

4. Conclusion

The production of the BPV is still at a very early stage (prototype) and the quantum of energy generated is not completely known. But this opens our doors to using plant-based resources as biofuels. The whole production process of the algae can be carried out at lower costs and can be done without any hassles. BPV can prove to be multi-purpose i.e production of electricity, absorption of carbon dioxide from air and also production of oxygen. BPV can also be used on facades giving a concept of green facades to the structures.

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3. Jenny Tschortner, Bin Lai & Jens O. Kromer "Biophotovoltaics: Green Power Generation From Sunlight & Water."

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Impact Of Green Curtain System on Indoor Environment Quality

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Abstract:
As society experiences a shift towards an increasingly indoor-centric lifestyle, the importance of maintaining optimal thermal conditions and air quality within living spaces becomes paramount for overall well-being. The surge in population growth has contributed to a transformation that, unfortunately, has led to compromised indoor air quality. Recognizing the impact of natural elements, incorporating them into indoor environments not only enhances air quality but also brings about various advantages such as improved well-being, psychological benefits, heightened cognitive function, and positive behavioral effects, thanks to biophilic influence on individuals. This research focuses on the implementation of an indoor vertical greenery strategy, specifically a living green curtain prototype, designed to function as a shading device for windows. The aim is to evaluate the potential benefits derived from such a system compared to scenarios without a curtain (control module) and with a traditional heavy curtain on external windows. Parameters such as temperature, relative humidity (RH), air quality, and solar radiation were meticulously measured within an indoor environment, with the analysis centered at the city Bengaluru, Karnataka, India.

The green curtain prototype comprises 20 small-scale hanging planters, each containing a variety of 6-inch plants chosen from 20 different species, strategically selected to enhance the purification of indoor air. Results indicate a noteworthy reduction in temperature, ranging from 0-3 degree Celsius compared to the control module, with a consistent 5-degree Celsius difference observed across distinct seasons. The evaporation effect attributed to the green curtain is evident in the recorded 67% increases in daily average relative humidity. This study demonstrates the potential ability of a green curtain to improve the indoor air quality and thermal comfort. The findings advocate for the integration of such sustainable, nature-inspired elements in architectural designs to create healthier and more comfortable living environments.

Keywords:
Green Curtain System, Air Quality, Thermal Comfort, Green Building, Sustainable Energy, Indoor Environment Quality, Relative Humidity, Biophilic Design

Introduction

Urbanization, defined as the transition from sparsely occupied land to densely populated cities, is accompanied by challenges such as the urban heat island effect, heightened air pollution, increased temperatures, and resource depletion (ugc, 2023;uttara, 2012). The repercussions of these issues contribute to climate change. Uncontrolled urbanization in India has accelerated environmental degradation, leading to concerns such as land insecurity, deteriorating water quality, excessive air pollution, and challenges in waste disposal (aggarwal, 2012).

The high building density in urban areas exacerbates resource consumption, with the building sector responsible for 40% of global energy usage, particularly due to the significant energy loads of heating, ventilation, and air conditioning (HVAC) systems. Inefficiency building service systems and poorly insulated external walls further contribute to this consumption. Notably, HVAC systems consume 50-70% of building energy, highlighting the need for improved control strategies to enhance energy efficiency. The Modern approach of recirculating air, while energy-efficient, poses challenges to indoor air quality (IAQ), leading to inadequate ventilation and subsequent poor IAQ. IAQ encompasses aspects like gaseous composition, humidity, temperature and contaminants, playing a crucial role in people's health, comfort, and well-being.

With individuals spending 90% of their time indoors, IAQ becomes a critical factor influencing productivity and satisfaction. Recent events, such as the COVID-19 pandemic, have further emphasized the importance of indoor environments, prompting strategies to isolate and maintain healthy indoor spaces. Introducing biophilic design strategies is imperative during the building life cycle to mitigate carbon dioxide emissions. Biophilic design, incorporating natural elements, fosters human-nature connectedness, positivity impacting health and well-being.

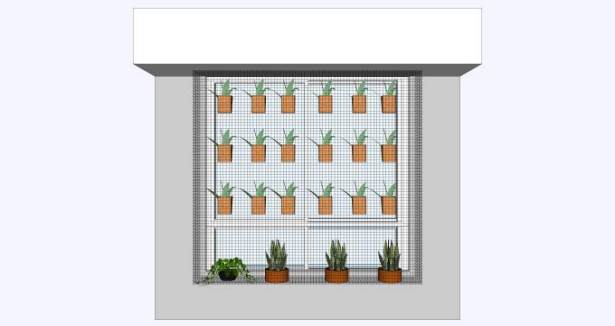
Various vertical greening systems, including green walls and living walls, have gained global popularity. These systems contribute to thermal comfort improvements, reduce energy consumption, and systems contribute to thermal comfort improvements, reductions in wall and roof surface temperatures, translating to 80-90% less heat transfer through building envelopes. External vertical greening addresses issues like biodiversity loss, urban drainage pressures, and cooling load reduction. However, the impact of vertical greening varies based on factors such as climate, plant species, and system design.

In particular, this research focuses on the impact of indoor vertical greening on IAQ, analyzing the effects

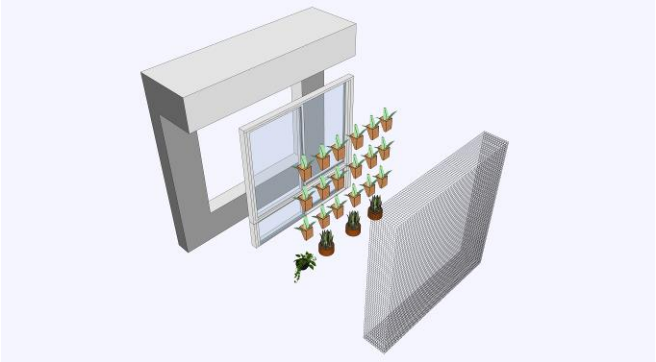
of 20 different plant species on indoor air quality. The study aims to assess the potential of this shading typology to enhance thermal comfort and IAQ in warm temperate climates. Performance comparisons include thermal comfort parameters (air temperature and relative humidity) and air quality among three modules: the prototype, a base case without shading, and an external window curtain. The findings aim to contribute valuable insights for residential applications seeking sustainable solutions for both comfort and air quality.

1. Methodology

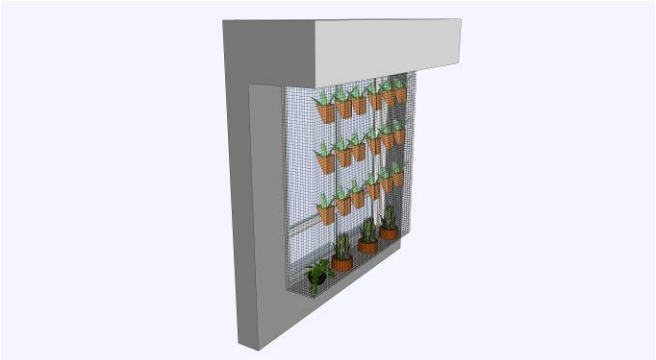
The methodology involves the design and construction of three modules: the No Curtain (NC), the Green Curtain (GC) module, and the Window curtain (WC) module, as depicted in Figure.1.



F1 window with green curtain



F2 view showing the construction of the module



F3 view

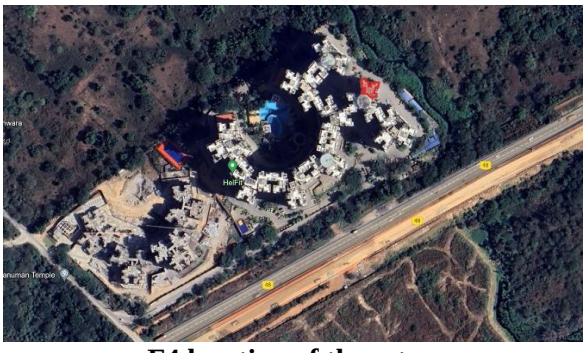
The initial module, NC, serves as a control or reference, with the window left unshaded and cleaned, simulating a room area exposed to maximum sunlight and receiving maximum solar gain from the window. The GC, the second module, is positioned on a same glass window panel with 20 nos. 6inch pots (a very conventional method used to create a green curtain). The third module incorporates a window curtain to fully shade the window from inside.

To create distinct environments for comparison, all three modules has been created on the window frame having clear glass in 6 inch concrete block wall. Enclosing the modules like rooms, as illustrated in Figure 1. This setup facilitates the comparison of indoor environments across different modules, revealing the effectiveness of the GC in enhancing thermal comfort and air quality.

For monitoring thermal comfort parameters and air quality, total weather stations are strategically placed near to the window. This comprehensive setup enables a detailed assessment of the impact of each shading typology on the indoor environment.

2.1 Location and Climatic Conditions

Bengaluru, also known as Bangalore, is in the southern part of India. It is the capital city of the Indian state of Karnataka. The geographical coordinates of Bengaluru are approximately 12.9716° N latitude and 77.5946° E longitude. It is situated on the Deccan Plateau and is known for being a major hub for information technology in India. This setup is being installed in flat no. M1201, Purva highlands located at Kanakapura Road near thalgattapura metro station, Bengaluru. Kanakapura Road is a prominent road in Bengaluru, Karnataka, India. It starts in the southern part of the city and extends towards the town of Kanakapura, which is approximately 55 kilometers from the center of Bengaluru. The road passes through various localities and neighborhoods, and its route is well-connected to the city's transportation network.



F4 location of the setup

The city generally experiences mild temperatures throughout the year. Summers are warm, with temperatures occasionally reaching above 30 degrees Celsius (86 degrees Fahrenheit), while winters are mild and relatively dry.

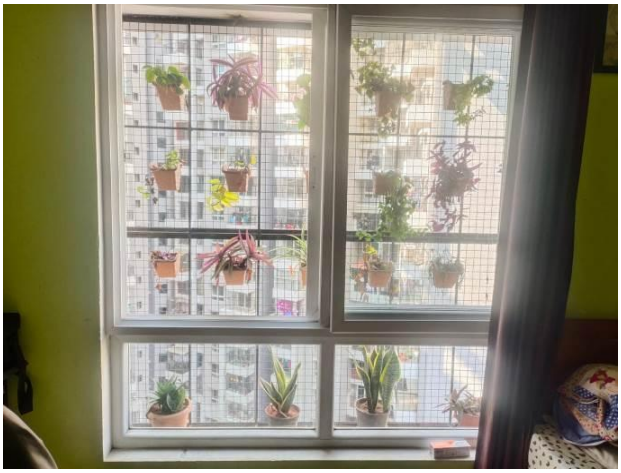
2.2 Experimental set-up

The module of the Green Curtain Prototype were positioned within an indoor space as shown in figure.

depicts the distinct components of the experiment in a modeled image. The modules were situated in an interior space, mimicking a room setup, while the surrounding environment was an urban context. This selection was made to assess the advantages of the green curtain in indoor module (room) conditions.

F5 M Block wing located in Purva highlands, Bengaluru.

The urban context of the set has a huge influence of nice roads in causing the heat island effect and also the air quality due to continuous heavy vehicular movement. 39º is also been recorded in the time of the summer.



F6 Experimental set-up

2.3 Design and Working Mechanism of Green Curtain Prototype

The working mechanism of the green curtain in a bedroom, comprising 20 conventional planters with indoor plant species, involves several key elements to create a harmonious and sustainable indoor environment. Each planter hosts carefully chosen indoor plants known for their air-purifying qualities and suitability for indoor conditions. The manual sprinkling water system is employed for watering, providing a hands-on and controlled approach to ensure optimal moisture levels for plant growth.

The process begins with the manual sprinkling of water onto the plants in the planters, promoting adequate hydration for the indoor greenery. The indoor plants, strategically placed along the bedroom walls, initiate a series of environmental benefits. First, through photosynthesis, the plants absorb carbon dioxide and release oxygen, contributing to improved air quality within the bedroom. This natural purification process helps create a healthier and more pleasant living space.

Moreover, the indoor green curtain acts as a thermal insulator, mitigating heat transfer between the bedroom and the external environment. This insulation effect contributes to enhanced energy efficiency, aiding in maintaining a comfortable temperature within the room. The carefully chosen indoor plant species not only add a touch of nature to the bedroom but also have calming and stress-reducing properties, creating a more serene and restful atmosphere. The manual watering system allows for a direct connection between the inhabitants and the green curtain, fostering a sense of responsibility for the well-being of the indoor plants. This process promotes improved air quality, thermal insulation, and a visually pleasing and calming indoor environment. The combination of carefully selected plants, manual watering, and strategic placement underscores the potential of green curtains to contribute to a sustainable and enjoyable living space within the confines of a bedroom.

2.4 Plant Specie

For this experiment, the ZZ plant, Spider plant, Snake plant Jade, Algerian ivy, Photos, Spiderwort, Oyster plant, Alovera, Money plant, Green Peperomia succulent plant, Tradescantia zebrina, crawling plant chosen was Philodendron cordatum, as depicted in **Figure 6.** This selection was based on its cost-effectiveness in terms of maintenance.

The green wall experiment features a thoughtfully chosen ensemble of plant species to enhance both the aesthetic and environmental aspects of the living space. The lineup includes the resilient ZZ Plant and adaptable Spider Plant, recognized for their air-purifying prowess. The architectural Snake Plant and visually striking Jade Plant add texture and structure, while Algerian Ivy cascades elegantly, contributing to the dynamic composition. Pothos and Spiderwort introduce varied foliage and trailing vines, creating visual interest. The Oyster Plant's purple-tinged leaves bring a splash of color, and the medicinal Aloe Vera contributes to both texture and air purification. The Golden Pothos and Green Peperomia offer cascading growth, and a variety of succulents ensure diversity with minimal water needs. The vibrant Tradescantia Zebrina and classic Philodendron Cordatum complete the ensemble, creating a lush and visually captivating green wall in the bedroom. This carefully curated selection not only elevates the room's aesthetics but also

promotes air quality, making it an ideal and sustainable addition to indoor spaces.

2.4 Data Arrangements

The prototype was outfitted with a total weather station for monitoring air temperature, relative humidity, air quality, and solar radiation etc. The Console, positioned inside the room, receives external data from the Integrated Sensor Suite and can be either placed on a table or hung on a wall. Within the Console, a compact data logger, specifically the Weatherlink data logger, is accommodated. This logger records weather-related information at user-selectable archive intervals. Additionally, the Weatherlink data logger is equipped with an interface facilitating seamless connectivity to a computer for the retrieval of data, enabling further analysis and record-keeping. This integrated system provides a user-friendly and efficient means of capturing and managing environmental data for various applications.

TEMPERATURE AND HUMIDITY SENSORS:

The Temperature and Humidity sensors are locainside the radiation shield which protects the sensors from solar radiation and other source radiated and reflected heat.

Temperature Sensors

- Inside Temperature (sensor located in console)
- Range +32° to +140°F (0° to +60°C)
- Sensor Accuracy ±1°F (±0.5°C)
- Update Interval 1 minute
- Resolution and Units Current Data: 0.1°F or 1°F or 0.1°C or 1°C
- (user-selectable) °C is converted from °F
- rounded to nearest 1°C , Historical Data
- Alarms: 1°F or 1°C (user-selectable)
- Outside Temperature (sensor located in ISS)
- Range -40° to +150°F (-40° to +65°C)
- Sensor Accuracy ±1°F (±0.5°C) above 20°F (-7°C), ±2°F (±1°C)
- under 20°F (-7°C)
- Update Interval 10 to 12 seconds
- Resolution and Units Current Data: 0.1°F or 1°F or 0.1°C or 1°C

Humidity Sensor:

(User-selectable) nominal (see Fig. Sensor Chart) °C is converted from °F rounded to nearest 1°C Historical Data and Alarms: 1°F or 1°C (user-selectable).

HUMIDITY

- Inside Relative Humidity (sensor located in console)
- Range 0 to 100% RH
- Accuracy ±3% (0 to 90% RH), ±4% (90 to 100%RH)
- Update Interval 1 minute
- Resolution and Units 1%
- Outside Relative Humidity (sensor located in ISS)
- Range 0 to 100% RH
- Accuracy ±3% (0 to 90% RH), ±4% (90 to 100%RH)
- Update Interval 50 seconds to 1 minute
- Resolution and Units 1%

BAROMETRIC PRESSURE included in console with a range of 610 to 1100 hPa.

Barometric Pressure

- Range 16.00" to 32.50" Hg, 410 to 820 mm Hg,
- 540 to 1100 hPa/mb
- Overall Accuracy ±0.03" Hg (±0.8 mm Hg, ±1.0 hPa/mb)
- Update Interval 1 minute
- Resolution and Units 0.01" Hg, 0.1 mm Hg, 0.1 hPa/mb (user- selectable)

ANEMOMETER

- Wind Direction
- Range 0 - 360°
- Accuracy ±3°
- Update Interval 2.5 to 3 seconds
- Display Resolution 16 points (22.5°) on compass rose, 1° in numeric display
- Wind Speed: Range 2 to 180 mph, 2 to 156 knots, 1 to 80 m/s, 3 to 290 km/h
- Accuracy ±2 mph (2 kts, 3 km/h, 1 m/s) or ±5%, whichever is greater
- Update Interval Instant Reading: 2.5 to 3 seconds, 10minute
- Average: 1 minute
- Resolution and Units 1 mph, 1 km/h, 0.5 m/s, or 1 knot (users electable) Measured in mph; other units are converted from mph and rounded.

2.5 Solar and Heat Energy Flow

The mechanisms of thermal transfer in the GC are convection (heat transport due to fluid motion), conduction (heat transfer due to molecular vibrations in a solid), and solar radiation (heat transport by photos). Part of the solar radiation is converted into heat and a part is biochemically stored by photosynthesis, and the reminder of the solar energy transmits through the clear glass sheet. Part of the thermal energy is absorbed by the plants via evaporation. The remaining thermal energy passes through the clear glass sheet.

The heat flowing inside the building consists of an incoming solar radiation and a heat convection.

$q^{Total} = q^{r}_{in} + q^{in}$ …(1)

This equation represents the combined effects of solar radiation and convection in contributing to the overall thermal dynamics within the Green Curtain system.

Where:

q^{Total} is the total energy;

q^{in} is the heat flowing by convective heat transfer;

q^{r}_{in} is the solar energy that passes through the clear glass (the last material layer in the GC module), which is given as

$$q^{r}_{in} = q^{r}_{out} - q_r - q_{ph} - q_h \quad \ldots(2)$$

where: q^{r}_{out} is the incoming solar energy outside the GC module;
q_r is the solar energy reflected by the GC;
q_h is the solar energy converted into heat inside the GC module;
q_{ph} is the solar energy used by plant leaves for photosynthesis by the chemical reaction below

$$6CO_2 + 6H_2O \xrightarrow{qph} C_6H_{12}O_6 + 6O_2$$

Photosynthesis selectively absorbs a portion of the solar spectrum, typically in the range of 400-700nm, spanning from violet to red wavelengths. The efficiency of photosynthesis, generally ranging from 3-6%, varies based on plant species and environmental conditions, with absorption percentages influenced by multiple factors. During photosynthesis, energy losses occur as heat due to the elevated temperature of the chloroplasts where the process unfolds. Furthermore, excess light energy can be dissipated, leading to potential leaf damage. The overall reflection (q_h) encompasses all processes converting radiation into heat.

The reflection of solar energy by plants, denoted as q_r, is associated with the albedo effect. Albedo quantifies surface reflectivity, representing the fraction of incident solar radiation reflected. Plant reflectance typically falls within the range of 5% to 30%, contingent on incident radiation wavelength and specific plant species.

Beyond radiation considerations, the heat flow through the Green Curtain (GC) module is accounted for by convection and conduction across various material layers. The assumption is made that the temperature variation across the GC is gradual, preventing thermal energy accumulation in material thermal masses. The thermal gradient is calculated using $\Delta T = qR$ in each solid phase, where R [Cm^2/W] is the R-value of the GC component, and $\Delta T = q_h^{in}$ each gaseous phase, where h [$W/(Cm^2)$] represents the heat convection coefficient of the air. A specific zone is designated for the leaves, where heat absorption (Q [W/m^3]) occurs due to combined effects of evapotranspiration and the fraction of solar radiation converted into heat.

$$Q = -Qet + q_h/D$$

where: Qet [W/m^3] is the energy lost by evapotranspiration in the GC module; qh [W/m^2] is the solar energy converted into heat, also called solar irradiance; D [m] is the thicknes of the folliage, $D = x_2 - x_1$.

The amount of energy required to evaporate water depends on several factors, including the initial temperature of the water, the atmospheric pressure, and the humidity of the air. However, on average, it takes about 2257 kilojoules (kJ) of energy to evaporate one liter of water at room temperature and at standard atmospheric pressure. This energy is used to overcome the intermolecular forces that hold the water molecules together, allowing them to break free and enter the gaseous phase. The power required to evaporate one liter of water in a day can be calculated as Power = Energy/Time = 2257 kJ/24 h = 94 W. Taking into account the fact that the average incoming solar radiation in the GC module is 50 W/m2 × 1.3 m × 1.1 m = 70 W and the average amount of water added to the GC plant is half a liter per day, the evapotranspiration (ET) will make a significant contribution to the energy budget. The temperature profile in the foliage is calculated by the steady state heat equation

$$d^2T/dx^2 = Q/DR_{eff}$$

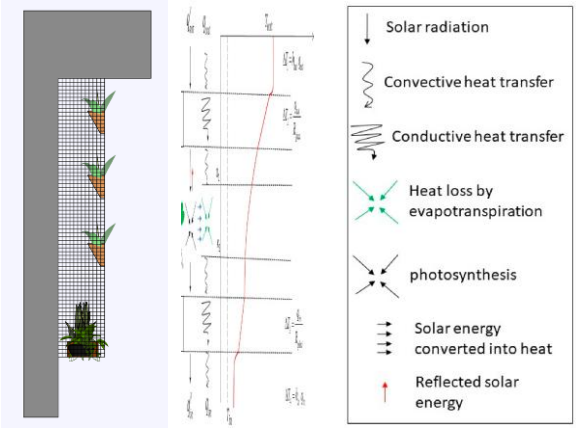
where R_{eff} is the effective R-value of the foliage and D is the thickness of the foliage. Solving this equation leaves the parabolic temperature profile as shown in Figure 7. The integration constants can be solved using the heat fluxes as boundary conditions, i.e., temperature and heat fluxes are continuous at the boundaries.

$$T_{out} - T(x_1) = (1/h_{out} + 1\ R_{glass})q_{out}$$

where:
T_{out} is the outdoor temperature;
h_{out} is the convective heat transfer in the outside environment;
R_{glass} is the R-value of the window glass.
The boundary condition at the point x^2 is given by

$$T(x_2) - T_{in} = (1/h_{in} + 1\ R_{glass})q_{in}$$

where: T_{in} is the indoor temperature;
h_{in} is the convective heat transfer in the inside environment after the clear glass sheet;
R_{glass} is the R-value of the clear glass.



F7 heat transfer

The governing equations show that the main effect of the evapotranspiration in the GC is to produce a drop of the heat flow indoors, $q_{in} = q_{out} - q_{et} + q_h$. In addition, the GC reduces the amount of solar radiation $q^{r}_{in} = q^{r}_{out} - q_r - q_{ph} - q_h$, allowing a comfortable natural lighting indoors. Without CG, the indoor heat flow will be raised due to lack of evapotranspiration and the

increase of indoor solar radiation. The main effect of the external blind is to drastically reduce the incoming solar radiation q_{out}, with a detrimental effect to the indoor natural illumination and creating discomfort for the indoor occupants.

2. Result & Analysis

The discussion of the results is organized into four distinct sections. The initial section focuses on the ambient conditions prevalent during the experiment. Subsequently, the second section delves into the analysis of solar radiation intensity and air temperature specifically within solar radiation hours. Moving forward, the third section comprehensively covers the recorded data for temperature and relative humidity throughout both solar and non-solar radiation hours. To enhance clarity, the temperature and relative humidity results are presented in the context of seasons: February represent the early summer and may is the peak summer, respectively. The concluding section addresses air quality, providing a holistic perspective on the varied aspects observed and measured during the experiment. This structured approach ensures a thorough exploration and discussion of each pertinent aspect of the experiment's outcomes.

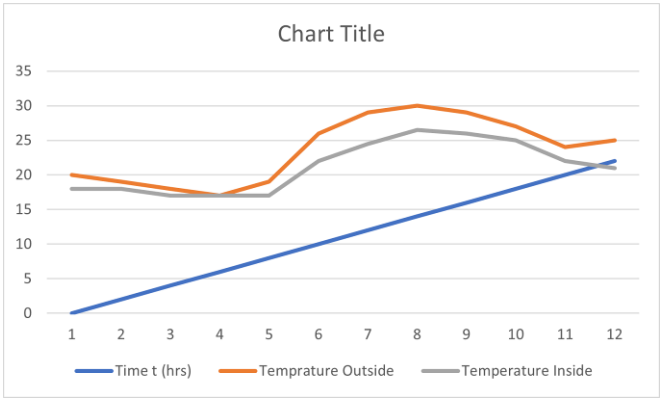
3.1 Ambient conditions

The experiment started in February 2023. It was recorded with mean daily maximum temperature 30.9º degree and minimum temperature 17.6º. Mean of Highest Maximum Temperature in the Month 33.7°C and Mean of Lowest Minimum Temperature in the Month 14.7°C, total rainfall (in mm) 7.1 and mean monthly rainy days 0.3 and Mean Wind Speed 4.4 kmph.During the study period of four months from February till May 2023, the highest recorded temperature was 39ºDegree, during the experiment, the maximum temperatures were recorded around 12:00hrs – 14:00hrs, while the minimum temperature was notices in the early morning hours before the sunrise.

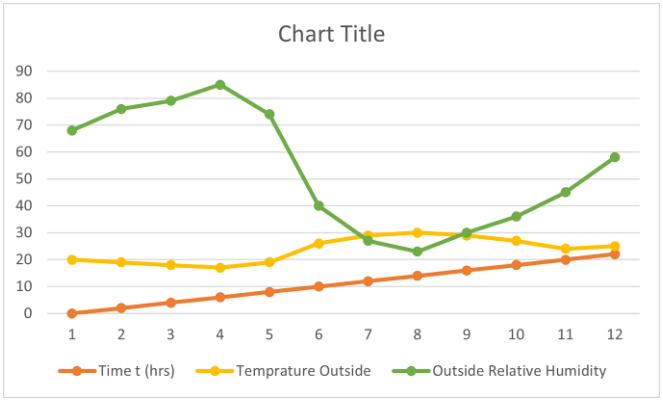
3.2 Solar radiation and Air temperature

The two external factors which had a high impact on the environment of the modules were the solar radiation (q^r_{out}) and the outdoor temperature T_{out}. As an example, the 1 February & May data of solar radiation and temperatures are shown in Figure respectively. The raw data of every day for Humidity and temperature are shown. The daily solar radiation ranged up to 540 W/m2 during the experiment. The mean value of solar radiation recorded was 38W/m2, though it kept increasing as the experiment moved into late summer (may). The solar radiation was directly impacting the outdoor temperature, which was then affecting the temperature of the modules inside.

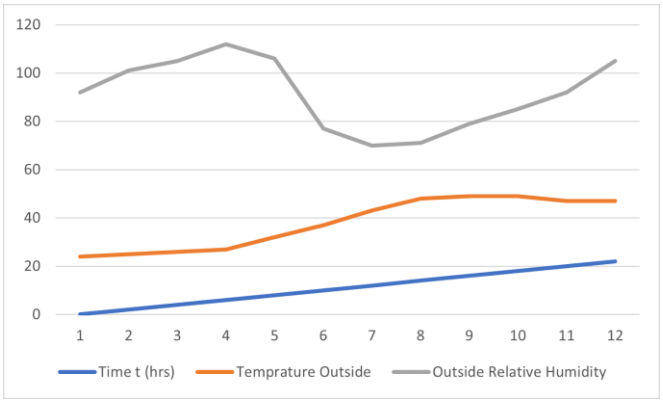
February Month Data



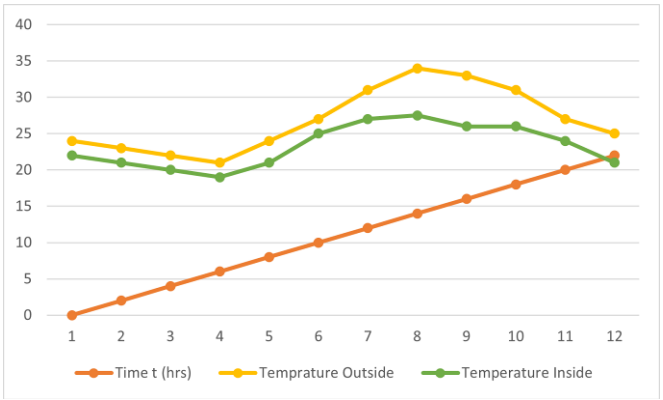
F 8 Temrature outside & Inside



F9 outside Relative humidity vs outside temprature - feb Month Data



F10 Outside temperature vs Outside humidity

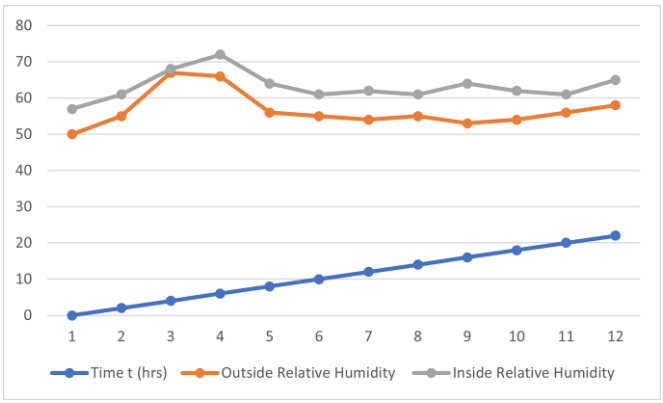


F11 Temprature Outside vs Temperature Inside

It is important to note that Figure 6 shows a pattern of three different time frames: (i) the rise towards the peak temperature; (ii) the peak temperature hours; and

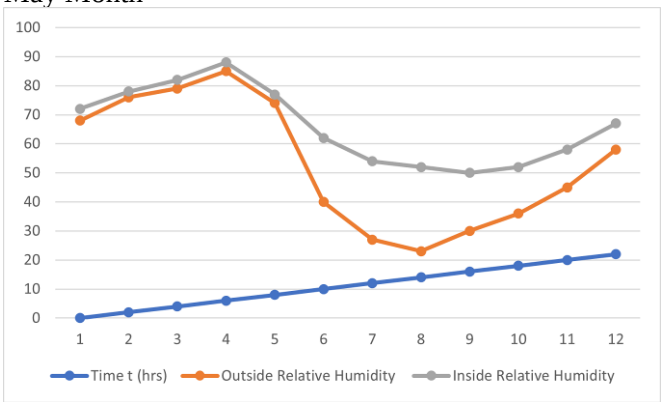
(iii) the fall of temperature after the peak has passed. The peak hours graph kept on changing monthly; e.g., in february, the peak hours were between 13:30–15:00 hrs, in may 12:00–14:30 hrs. High- temperature peaks were noticed in the NC module from late spring to late summer. The primary peak occurred around 12:00hrs in late spring and slightly late in early summer at 14:00hrs. however a secondary peak was noticed in early summer at around 13:30hrs. in mid summer two primary peak were noticed at 13:30 hrs and 14:30 hrs, with temperature 33.5ºC each, respectively. During the peak hours, the GC always had a minimum value compared to The NC and was the quickest to cool when the peak was passed. It was primarily because of the evapotranspiration effect of the plants in the GC module. The cooling down effect after peak hours was also noticed in other studies. The peak were found in NC module the most was the entrapped heating being generated due to greenhouse effect.

4 ***Temperature and Relative Humidity*** - February Month

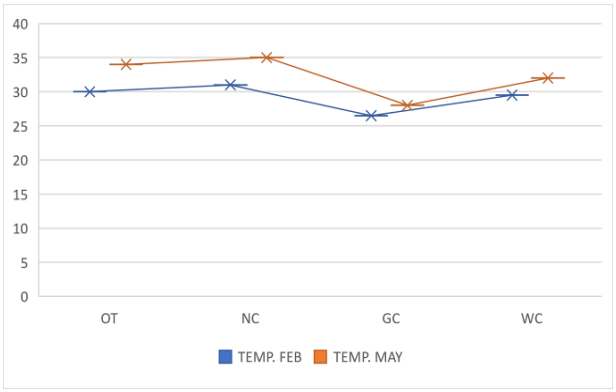


The maximum and minimum temperatures also ranged significantly within each season shown in fig.. It was important to note that the temperature range increased during the seasonal shifts; e.g., the largest temperature range overall was recorded in the NC module during February month (min = 17 °C, max = 30 °C), while the maximum in the GC was found in between 16 °C (min) and 26.5 °C (max).

May Month

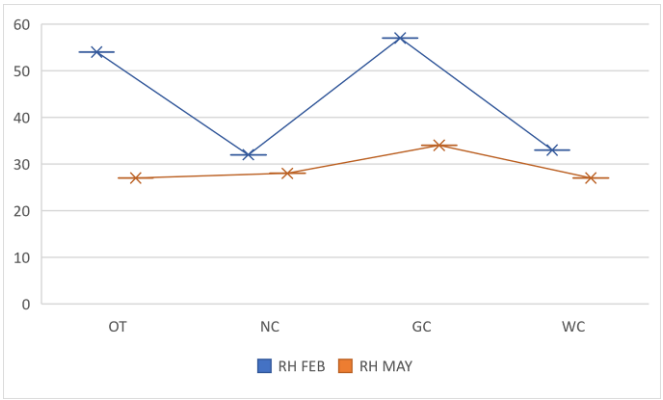


F12 Outside relative humidity vs Inside Relative humidity



F13 Temperature for different modules (OT(outside temperature), NC(no curtain), GC(green Curtain), WC(Window curtain))

The RH data are shown in Figure 14 . GC had the highest RH in all the modules from may and February. On a daily average basis, in late spring (November), the RH of GC was greater than OT, NC, and WC around 7%, 6%, and 5%, respectively.



F14 Relative Humidity for different modules (OT(outside temperature), NC(no curtain), GC(green Curtain), WC(Window curtain))

3. Conclusion

Vertical greening in form of green walls or living facades are used in buildings to improve air quality, reduce the urban heat island effect, provide habitat for wildlife, reduce noise pollution, and enhance the biophilic character of buildings. On the other hand, the indoor vertical greening system is less common and poorly investigated. This research is unique in developing an innovative indoor vertical greening in the form of a green curtain within an indoor setting of a prototype room. The green curtain provides to the occupants full control of the amount of sunlight that is allowed into the indoor environment based on the innovative rotating mechanism of its modules, allowing us to adjust the indoor natural light and the exposure of the plants to the required solar radiation needed for effective evapotranspiration. We demonstrated positive impacts on air temperature and air quality consistent with findings from outdoor greening studies. It was found that, during the peak solar radiation hours from

February to May, the difference between NC and GC air temperatures was mostly between 0–4 _C. On hotter days, during the peak hours, with regard to the maximum difference between NC, GC, and WB, GC was as high as 8 _C and 4 _C, respectively. In the after-peak hours, during the summer months, the GC module was cooler than the NC. Overall, the GC created a climate in an intermediate space of the module that was characterized by lower temperature, heat absorption, higher humidity, and improved air quality in the evening hours. While the GC would not significantly affect the temperature/humidity indoors, it produces a significant reduction of the heat flow in the building envelope due to the combined effect of evapotranspiration, reflected solar radiation, and photosynthesis. The implication of the initial findings is vast, as a simple indoor solution without any retrofitting requirement or an alternative to an energy-saving retrofit strategy for windows provides a feasible option to mitigate heat gain. Moreover, we optimized two main thermal comfort factors, air temperature and relative humidity, in the desired range, that improve thermal comfort. In addition, the design adopted a biophilic design approach that creates a natural indoor environment, providing the benefits of biophilia by bringing the green outdoors indoors. High humidity levels were observed near the living wall due to plant evapotranspiration, which is beneficial in the case of dry indoor environments.

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As the dedicated founders of "Peoples Design Studio (PDS)," our shared passion for architecture is underpinned by a profound belief in the pivotal role of research in advancing innovative design solutions. Operating on the principle of creating inclusive and harmonious spaces, PDS specializes in architecture that resonates with the general populace. The studio's extensive portfolio encompasses Architecture, Urban Design, Green Building Strategies, Energy Efficiency, Performative Designs, Acoustics, Sustainable Materials, and more. With a commitment to connecting people with nature, PDS strives to craft meaningful environments that transcend conventional boundaries, elevating the human experience through thoughtful design interventions.

Feasibility Of Earth Energy as A Solution for Rural Energy Demand

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Abstract:
Access to electricity in rural India greatly challenges the energy sector. In 2011, approximately 400 million people in India had no electricity. This lack of access causes many problems for rural Indians. Electricity is a crucial factor in the development of any society since it is related to our daily lives. About 60% of India's total population lives in rural areas, where access to reliable electricity is either limited or non-existent. There are various methods of energy production, including renewable and conventional sources. However, most of them have certain drawbacks, such as high costs, negative environmental impact, and limited availability. A Sustainable Earth-Battery can be used as an alternative power source as there is no need for external power to charge the Earth-Battery because it can get charged naturally in the presence of water. Earth Battery is a biological battery capable of producing electricity by feeding on natural soil and using plants to maintain the ecosystem without damaging it. This project is a highly eco-friendly initiative that is both cost-effective and easy to implement. It involves a straightforward process that utilizes natural resources to generate electricity. The building's overall energy consumption accounts for 37% (i.e. 213 M.tone) of India's total annual primary energy consumption. Using the earth as a source of energy can be a significant step towards sustainability as it does not require any chemicals or conventional methods to produce energy. Therefore, it is crucial to conduct research in this field to gain a better understanding and application of this energy source. In this research, we will be using different types of soil, such as loam soil, clay soil, and dry clay soil, along with compost and cow dung to test the amount of energy that can be produced. To measure the energy production, we will be using a digital device called a multimeter, which is used to measure various electrical values like voltage (volts), current (amps), and resistance (ohms). Using the energy generated from soil, compost, and cow dung to power a small fan and light a bulb.

Keywords:
Earth Battery, Rural Energy, Soil Types, Sustainable Energy Source.

Introduction

Access to electricity in rural India greatly challenges the energy sector. In 2011, approximately 400 million people in India did not have access to electricity. This lack of access causes many problems for rural Indians. Electricity is a crucial factor in the development of any society since it is related to our daily lives [12].
REC India reports that there are currently 88 villages in Maharashtra that are without access to electricity. News reports reveal frequent power outages affecting many Maharashtra villages. For instance, for the past 10 days, 60 villages in Nashik have been experiencing power outages and are without electricity (Hindustan Times). Two-thirds of households in India face power outages, with one-third experiencing outages of more than two hours daily, according to a Local Circles survey cited in a (Business Today) article.

Around 75% of the total energy consumption in rural areas is utilized for domestic purposes. The majority of the rural population still depends on traditional fuels such as firewood, animal dung, and crop residues, as well as human and animal energy to fulfil most of their energy requirements [11]. Villagers primarily rely on biomass fuels like wood, cow dung, and agricultural residues for cooking, which are often burned in inefficient traditional cook stoves. The main fuels used for lighting in rural households are kerosene and electricity, if available. Otherwise, they live in darkness. Lighting is not only for doing the visual task in the rural household but it is a lifesaving from dangerous animals such as snakes and scorpions. . Electricity is also necessary for studying, doing Household chores, and working in the fields. For instance, water is pumped using motors, which require electricity. The electric motors are used mainly for water lifting and to a limited extent for stationary operations, such as threshing, grain cleaning, milling, and crushing [9].

Without a proper supply of electricity, people in rural India resort to traditional methods of doing things, which waste their time and reduce their productivity. Women continue to suffer ill- effects on their health because they have no choice but to burn poor-quality biomass fuels in their ill–designed cook stoves. India is a developing country, and we need clean and affordable energy for our villages to grow economically and mentally through education. Most villagers cannot afford high electricity bills. The situation for rural people in India appears bleak, with projections indicating a continued dependence on traditional fuels and few prospects for improvement. Many challenges need to be addressed, so developed rural households need to find alternative solutions to their problems. It is important to remember that the growth of a village can contribute to the overall growth of the country.

About 60% of India's total population lives in rural areas, where access to reliable electricity is either limited or non-existent. This lack of access forces a large portion of the rural population to rely on less efficient and often harmful energy sources such as wood, diesel, and kerosene to meet their energy needs. (Nisha Thirumurthy, Laura Harrington, and Daniel Martin National Renewable Energy Laboratory). The difference of consumption of energy and generation is 10406 mu. (Times of India)

In rural India, the local community relies on a combination of renewable and non-renewable energy sources to meet their energy needs.
Table 1: The different sources of energy for rural areas and their associated issues.

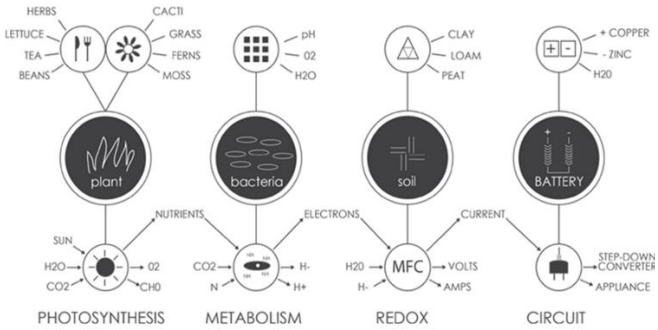
S.No.	Source Types	Issue
1.	Solar panel- (renewable source)	1. The high cost of the solar panel and the insufficient efficiency. An average of 1 square. The meter solar panel area produces no more than 120 Wh of useful power. This energy is not enough even for a computer. 2. The average efficiency of solar panels used for the power supply of buildings is 14%, which is less than the efficiency of traditional energy sources. 3. Requires sunny weather to work best 4. Cannot be used at night 5. Manufacturing of solar panels can harm the environment 6. Disposal of old solar panels harmful to the environment
2.	Bio-gas- (Renewable source)	1. Unstable and hazardous. 2. Initial costing is higher. 3. Contains Impurities
3.	Windmills- (Renewable)	1. The energy harvested from wind is directly proportional to the windward area of the turbine. 2. Wind farms are required to be centrally situated in geographic locations featuring less populated, more open terrain with high wind energy quality. 3. Devices predominantly rely on batteries with a limited lifespan, necessitating frequent maintenance and replacement. 4. Such processes bear significant costs while also posing environmental hazards. 5. Mid-high power demands 6. Wind speed needed 7. Noise level high
4.	Grid- (Non-Renewable source)	1. Costly to build. 2. Environmental hazards. 3. A large number of main power needed. 4. Not economical.
5.	Wood (Non-Renewable source)	1. Dirty because when burning it gives off smoke and soot. 2. Pollutes the environment through the gases it emits. 3. Its overexploitation leads to deforestation leading to problems of soil erosion, Global warming, and shortage of water. In India, the cost of firewood is around Rs. 7 per kg. (India mart)
6.	Kerosene – (Non-Renewable source)	1. WHO discourages the use of kerosene in households due to potential health risks such as cardiovascular and respiratory mortality. 2. The prices per ltr are between Rs. 65-75, which is considered very high for villagers.
7.	Diesel- (Non-Renewable source)	1. Diesel fuel usually costs more 2. To minimize exposure to flames and sparks when it is used as fuel, it must be stored, transported, and handled with proper caution 3. Diesel engine emissions can lead to ozone formation in the atmosphere, which is very harmful to crops, trees, plants, and other living organisms. 4. The number of particles that enter the lungs rises due to exposure to diesel exhaust fumes, triggering the risk of lung infections and illnesses. 5. Skin cancer and CNS problems have been linked to long-term diesel exposure.
8.	Coal – (Renewable source)	1. Coal generates carbon emissions. 2. Coal mining and combustion contributes to climate change 3. The sources of coal-related deaths include such issues as premature deaths, suffocation, asthma, pneumonia, lung cancer, and oxygen deprivation. 4. The cost of coal ranges from Rs. 32 to Rs. 45 per kg.

1. **WHAT IS EARTH BATTERY**

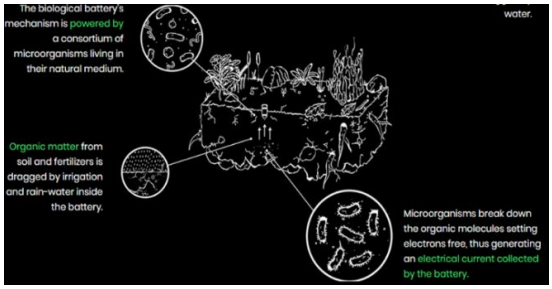
The renewable energy and alternative power sectors are rising with less global warming,

improved public health, inexhaustible electricity, and affordable energy prices day by day. A Sustainable Earth-Battery can be used as an alternative power source as there is no need for external power to charge the Earth-Battery because it can get charged naturally in the presence of water[]. Earth Battery is a biological battery capable of producing electricity by feeding on natural soil and using plants to maintain the ecosystem without damaging it. Bio Panel is composed of a soil area in the upper part (acting as an extra source of organic matter) and the Microbial Fuel Cell (MFC), located in the lower part. The MFC generates electricity by a Redox reaction happening in the soil of the second layer, between the anode, where the bacteria is fuelled by the organic matter of the soil, and the cathode in contact with the oxygen from the air.

MFC was first reported in 1911, bio electrochemical systems (BES) converting the chemical energy contained in reduced organic matter into electrical energy have recently received great attention, as illustrated by the number of publications on the subject [6].



F1: current production (https://www.biootech.com)



F2: current production (https://www.biootech.com)

3. WHY SUSTAINABLE BATTERY

The project is a highly eco-friendly initiative that is both cost-effective and easy to implement. It involves a straightforward process that utilizes natural resources to generate electricity. The building's overall energy consumption accounts for 37% (i.e. 213 m.tone) of India's total annual primary energy consumption. This energy can be replaced through the use of green energy sources such as solar panels. However, recycling solar panels is a difficult process that can be harmful to the environment. Therefore, it is important to explore alternative options to meet our energy demands sustainably.

4. LITERATURE REVIEW

A paper by Mohammad sajedur Rahman, Nural Huda Sakib find that in rural areas, there is a shortage of electricity supply and required technologies to meet the demand. An important issue for rural areas is the delivery of electricity, which is impacted by the infrastructure, administrative policies, and regulations.Power plants should be built in rural areas to provide electricity.

Md. Samiul Islam Bornoa,b,c,, Md. Sayeduzzamana,c, Khan Md. Elmea,c,Md. Hasibul Islama,c, Md. Abdur Rahman, In his research he find that ,

- This mechanism used a renewable energy source that encouraged the use of green energy. Since it does not emit CO2, CFC and does not contain any chemical compounds, this prototype is not harmful to human beings. If more funds were available to build this prototype, it would be more affordable than any other renewable energy source. It
- Will be the simplest solution to the most challenging problem in the field of electricity. If the system can be widely implemented commercially, the overall implementation cost can be minimized and it can be applied more efficiently. The expenditure can be recovered faster than other renewable energy sources such as solar power, solar thermal power, and wind power because of its inexpensive installation cost, which will eventually help the stakeholders to gain profit. Electricity consumption is high in today's world. The energy crisis, or long-term load shedding, affects a large number of people. As a result, a solution for more efficient electricity generation was developed. Produce electricity with readily available raw materials and no-cost soil.
-

Xavier Alexis Walter , John Greenman, Ioannis A. Ieropoulos in his reach he find that –

- **(Microbial fuel cells directly powering a microcomputer)**

To be used as an energy source Microbial fuel cells are often seen as too unstable and incapable of producing directly exploitable energy levels. Employing power management systems has been a solution exploited so far to remediate the intrinsic current instability and low-power density of microbial fuel cells. Hence, all reports that have demonstrably powered applications with MFCs used power management circuitry. The results presented here demonstrate for the first time that a microcomputer can directly and continuously be powered by MFCs without any energy management apparatus. The 4-module S-MFC cascade continuously

produced 2.55 V and 61 mA, a total of 130 mW, which is above the minimum requirements of the microcomputer and its screen (GBC). However, results showed that producing enough power is not sufficient to directly power an application. Indeed, although the 3-module cascade produced sufficient power to cover the GBC requirements (150 mW; 82 mA), the voltage was below the threshold level at which the GBC is programmed to switch OFF (1.832 V). This showed that the system had to be calibrated to meet the application-specific needs, which in this case was a voltage higher than 1.832 V. Due to its modular nature, the MFC system can be adapted to any scale of use and yet be energy-positive, which is a feature not always found in other biotechnologies (e.g. Biogas). Although the results demonstrated that a MFC system can directly and continuously power a microcomputer, there is room for improvement, especially on scaling the system to the end application. A key aspect that would require attention, especially in terms of employing MFCs as a power source, is to explore the robustness of such system over a long period of time and investigate the stability of the series electrical connection.

Elvis Fosso-Kankeu, Sanette Marx, Frans Waanders and Visagie Jacobs

- **(**Impact of soil type on electricity generation from a Microbial Fuel Cell)

Compound	Value (%)	
	Black soil	Red soil
Aluminium oxide (Al_2O_3)	9.158	43.165
Calcium oxide (CaO)	37.584	0.420
Cloride (Cl)	0.795	0.024
Iron(III) oxide	5.234	6.830
Lead(II) oxide (PbO)	0.120	0.010
Magnesium oxide (MgO)	1.598	0.000
Manganese(II) oxide (MnO)	0.151	0.021
Phosphorus pentoxide (P_2O_5)	1.758	0.108
Potassium oxide (K_2O)	2.380	0.447
Silicon dioxide (SiO_2)	35.445	147.823
Sodium oxide (Na_2O)	0.286	0.053
Sulfur trioxide (SO_3)	5.162	0.183
Titanium dioxide (TiO_2)	1.094	0.773
Zinc oxide (ZnO)	0.080	0.015
Zirconium oxide (ZrO_2)	0.070	0.052

- Soil has a positive impact on the electricity generation in a microbial fuel cell. From the three soils tested (sand, silt, clay) the clay was most promising, with a peak voltage of 644 mV and a peak power density of 0.0885 (mW/mm2).The one to one, soil to compost ratio configuration worked the best for electricity generation. The pure compost MFC did generate electricity, but the SMFC's which had a soil-compost ratio outperformed the pure compost configuration. Further investigation is required to better understand the mechanisms by which the soil type affects the electricity generation in the SMFC.

5. LITERATURE REVIEW OUTCOME

5.1 SOIL

A thin layer of disintegrated rock particles, organic matter, water, and air that covers most of the land surface is known as soil. Soil is considered a biological laboratory with a multitude of living organisms.

Soil is classified into four types:

i. Sandy soil
ii. Silt Soil
iii. Clay Soil
iv. Loamy Soil

Soil microorganisms can be categorized into five groups:

i. Bacteria,
ii. Actinomycetes,
iii. Fungi,
iv. Algae, and
v. Protozoa.

Each of these groups has unique traits that define them and their roles in soil. The rhizosphere, which is the area around plant roots, is home to up to 10 billion bacterial cells per gram of soil.

Property of soil

Fertile soil usually contains 106–
109 bacteria per gram of soil (Tugel and Lewandowski 1999). They play a vital role in soil
texture by their organic secretions. Microorganisms are usually higher in the A horizon, and
they contribute to the formation of the granular structure. Soil microorganisms consist of both prokaryotes and eukaryotes, including bacteria, protozoa, algae, fungi, and actinomycetes

- Fertile soil usually contains 106–109 bacteria per gram of soil (Tugel and Lewandowski 1999).
- Microorganisms are usually higher in the A horizon, and they contribute to the formation of the granular structure.

Soil microorganisms consist of both prokaryotes and eukaryotes, including bacteria, protozoa, algae, fungi, and actinomycetes [1].

Nutrients value of Soil

Nutrient*	Vermicompost
N (%)	1.6
PO (%)	0.7
KO (%)	0.8
Ca (%)	0.5
Mg (%)	0.2
Fe (ppm)	175.0
Cu (ppm)	5.0
Zn (ppm)	24.5
Mn (ppm)	96.5
C:N Ratio	15.5

(A.SALEH ET.AL. ,2019)

5.2 COMPOST

Composting is a process that converts organic materials into compost- a nutrient-rich soil amendment through natural decomposition [10].

Property of compost

- Chemical fertilizers and pesticides reduced.
- Composting also solve the problem of waste
- Enhances plant growth, boosts crop yields.
- Improves water quality by filtering stormwater, and reducing nutrient and sediment runoff.

5.3 COW DUNG

Cow dung is the term used to refer to the waste material produced by bovine animals such as domestic cattle, bison, yak, and water buffalo. This waste material, also known as cow pats or cow manure, is the undigested residue of plant matter that has passed through the animal's gut. Cow dung is rich in beneficial microbes such as Saccharomyces, Lactobacillus, Bacillus, Streptococcus, and Candida, and it contains several nutritional components like minerals, vitamins, potassium, nitrogen, oxygen, carbon, cellulose, hemicellulose, mucus, and lignin.

Property of cow dung

- Cow dung is a rich source of microorganisms, containing over 60 different bacterial species, 100 species of protozoa, and yeast.
- Biodegradable and eco-friendly
- An effective fertilizer enhances the fertility of the soil.

5.4 CATHODE & ANODE

Cathode is the negative part of the cell where reduction takes place. A cathode is the metallic electrode through which current flows out in a polarized electrical device. The Anode is the negative or reducing electrode that releases electrons to the external circuit and oxidizes during and electrochemical reaction.

Various kinds of electrodes such as Copper (Cu29), Aluminum (Al13), Zinc (Zn30), and Carbon (C6) were investigated for the Anode and Cathode. Copper and Aluminum (Al13) were selected due to high electron mobility and conductivity that showed better performance [6]. The electrode's size and materials were changed. Finally, the electrode's size was fixed at 0.07 m in length, the diameter of the Carbon (C6) electrode was 0.012 m, and the Aluminum (Al13) electrode was 0.007 m.

5.5 MULTIMETER

A digital multimeter is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps), and resistance (ohms).

F3 (Author)

5.6 WIRE

Wires are made from metals. Some of the metals used include steel, copper, aluminum, and silver. Copper wires/cables are the best electric wires for wiring due to their high conductivity, low electrical resistance, and durability. Copper wires can handle high loads of electricity and are resistant to corrosion, making them a reliable choice for long-term use.

F4: (Author)

F5: (Author)

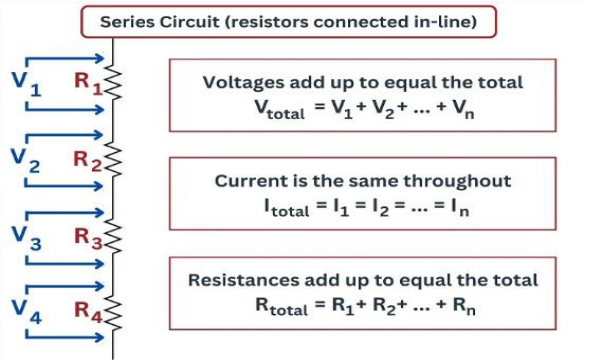
5.7 CONTAINER

Plastic cups and planters were utilized to hold materials like cow dung, soil, and compost for creating batteries. Plastic is non-reactive and doesn't react with anything. Its life cycle is also very long, and it doesn't get damaged due to moisture or anything else. Using plastic cups and planters for this purpose helps in solving the problem of plastic waste. Additionally, reusing and recycling it is an excellent step towards preserving the environment. This approach is sustainable and promotes a greener future.

5.8 SERIES CONNECTION

1) ***VOLTAGE***

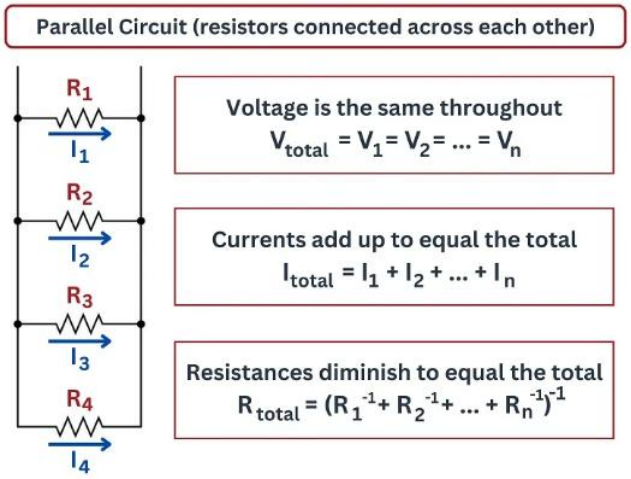
In a series circuit, the voltage is the sum of the voltage drops of the individual components (resistance units).Series circuits are defined by having only one path for current, and this means the steady-state current in a series circuit must be the same at all points of that circuit. It also means that the sum of all voltages dropped by load devices must equal the sum total of all source voltages, and that the total resistance of the circuit will be the sum of all individual resistances. (https://control.com/textbook/dc-electricity/series-versus-parallel-circuits).



F6: (https://control.com/textbook/dc-electricity/series-versus-parallel-circuits).

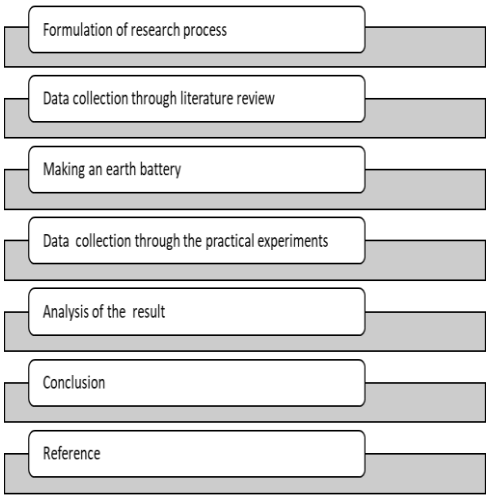
5.9 PARALLEL CONNECTION

The defining characteristic of a parallel circuit, by contrast, is that all components share the same two equipotential points. "Equipotential" simply means "at the same potential" which points along an uninterrupted conductor must be. This means there can be only one value of voltage anywhere in the circuit, the exact same voltage for all components at any given time. (https://control.com/textbook/dc-electricity/series-versus-parallel-circuits)



F7: (https://control.com/textbook/dc-electricity/series-versus-parallel-circuits).

6. METHODOLOGY



7. MATERIALS REQUIRED FOR EXPERIMENTS

1. Soil
2. Cocopit
3. Compost
4. Cow dung
5. Multimeter
6. Cathode anode
7. Wire
8. 12 v LED Light

8. METHOD OF EXPERIMENTS FOR CHECKING THE VOLATAGE PRESENT IN THE SAMPLE.

- Collecting the soil, compost, cow dung and coco-pit sample.
- Taking sample into clean plastic glass or (direct planter soil) to put soil into it.
- Making anode and cathode which make from the old batteries.
- Taking two different colored wire.
- Taking multimeter to measure the results.
- Attached cathode and anode at the end point of both the wires and the one points put inside the sample of both the wires.
- Take multimeter and join the next end of the both wires.
- Now on the multimeter and take a reading of the voltage provided by the sample.
  After getting the results and prove of presences of voltage than the sample is further taking to make the series connection and taking the new resultant value.

9. METHOD OF EXPERIMENTS FOR ADDITION OF THE VOLATEGE AND LIGHTING 12 V LED LIGHT.

- Collecting the soil, compost, cow dung, and coco-pit sample.
- Taking the sample into a clean plastic glass or(direct planter soil) to put soil into it.
- Making anode and cathode which are made from old batteries.
- Taking two different colored wire.
- Taking multimeter to measure the results.
  - Attached cathode and anode at the end point of the wire, make the 9 same pieces
  - And dip cathode at one glass and anode at the other glass (filled with sample) and repeat the same process with all the 9-sample glass.
  - At the end join the two wire at cathode and anode at other end of wire join with multimeter to take reading.
  - After taking reading join the 12v LED

10. DATA COLLECTION THROUGH EXPERIMENTS

1. Dry Clay soil

Test is conducted on Soil kept on Pot. Completely Dry Soil were absence of moisture.

Value get - .05 v

2.Loam soil & Coco pit Mix

Test is conducted on Soil and Coco Pit Mix used for Money plant. At the time of Testing, we notice that moisture is present on the it.

Value get - .29v

F8:Author)

F9:

3.Loam Soil

Test is conducted on Soil used for Tulsi Plant Test is conducted on Soil used for Tulsi Plant.

Value get -.47v

*4.**Clay Soil***

Test is conducted on Soil under the Big Tree on Park.*Value get- .45v*

F10: (Author)

F11: (Author

*5. **Clay Soil***

Test is conducted on Lawn area of the Park.

Value get- .43v

6. Partly sandy soil

Test is conducted on Red Soil available for Gardening.

Value get- .45v

7. Compost

Test conducted on freshly made compost which is made from household waste and leaves.

Value get .54V

8. Cow Dung

Test Conduct on fresh cow dung collected form the Farm.

Value get .58V

11. RESULTS OF SINGLE UNIT SAMPLE

S .N	Sample Types	Day1			Day 2		
		Morning	Afternoon	Night	Morning	Afternoon	Night
1	Dry Clay	0.05	0.05	0.05	0.05	0.05	0.05
2	Loam soil & coco pit mix	0.29	0.29	0.29	0.29	0.29	0.29
3	Loam soil	0.47	0.47	0.47	0.47	0.47	0.47
4	Clay soil	0.45	0.45	0.45	0.45	0.45	0.45
5	Partly sandy soil	0.45	0.45	0.45	0.45	0.45	0.45
6	compost	0.54	0.54	0.54	0.54	0.54	0.54
7	Cow dung	0.58	0.58	0.58	0.58	0.58	0.58

Day 3			Day 4			Day 5		
Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoo	Night
0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58

Table : 2 (Author)

12. SERIES CONNECTION AND ITS RESULT SOIL

The energy generated is used to power a small LED light with a voltage of 2-3 volts. The light is illuminated using earth energy and various colors of LED lights have been tested.

The voltage of the 12v LED light is powered by a 9-sample glass additive that results in around 12v.

12v LED light is lit through small prototype of earth battery

13. RESULTS OF SERIES CONNECTION SAMPLE

SERIES CONNECTION RESULTS						
S.NO.	Sample	Single sample (volts)	2 sample are connected through series connection (volts)	3 sample are connected through series connection (volts)	4 sample are connected through series connection (volts)	9 sample are connected through series connection (volts)
1	Dry Clay	0.05	0.1	0.2	0.21	
2	Loam soil & coco pit mix	0.29	0.54	1.2	1.5	
3	Loam soil	0.47	0.99	1.7	2.04	12v
4	Clay soil	0.45	0.98	1.6	1.9	
5	Partly sandy soil	0.45	0.95	1.54	1.86	
6	compost	0.54	1.1			
7	Cow dung	0.58	1.2	2.1	3.2	

Table: 3 (Author)

14. RECOMMENDATION:

[1] Use the moisture contain sample

[2] Sample should be pure

[3] Equipment's should be clean

15. COMPARISION

COMPARISION BETWEEN SOLAR CELL AND SUSTAINBLE BATTERY							
Sources	Single unit	Size	Energy produced V	Avilable size in market	No. cells	Energy produced V	Solar cells
SOLAR	1	125*125 MM	0.5-0.6	39* 65*+_2	60	30	In a typical module, 36 cells , are connected in series to produce a volts sufficent to charge a 12 v battery
Dry soil	1	SIZE DOES NOT DEPENDS IT CAN BE AROUND 75*75MM	0.05	NO FIXED SIZE	60	3	
Loam soil & Coco pit	1		0.29		60	17.4	
Loam soil	1		0.47		60	28.2	
Clay soil	1		0.43		60	25.8	
Partly saandy soil	1		0.45		60	27	
cow dung	1		0.58		60	34.8	
compost	1		0.54		60	32.4	

Table: 4 (Author)

16. ANALYSIS

Based on the experiments conducted on-site, the collected data indicates that a small prototype of a soil earth battery, made up of 9 plastic cups filled with approximately 150–200 grams of soil, can generate around 12 volts of electricity to power a 12 volt LED light. These findings suggest that if the prototype is expanded and more cups are added in series, the voltage output will increase accordingly. For instance, connecting 3–4 cups will light up a single 2V LED

light, whereas connecting 9 cups will produce 12V. This proves that as more cups are connected in series, the voltage output will increase proportionally. To cater to the electricity needs of rural India, the scale and series of the soil earth battery can be increased to supply individual units within the village. Based on our on-site experiments, the data collected shows that a small prototype of a soil earth battery, consisting of 9 plastic cups filled with approximately 150–200 g of soil, is capable of producing around 12 volts of electricity to power a 12 volt LED light. These results suggest that if the prototype is scaled up and more cups are added in series, the voltage output will also increase. For example, connecting 3–4 glasses will light a single 2V LED light, while connecting 9 sample glasses will produce 12V. This proves that as more samples are added, the voltage output increases proportionally. To address the electricity needs of rural India, we can increase the scale and series of the soil earth battery to supply individual units within the village.

17. CONCLUSION

In rural areas, the management of cow dung waste is often neglected, which poses a significant threat to environmental preservation and health. Cow dung waste is generally perceived as having no value and is severely underestimated by the local community. Even cattle farmers tend to overlook the importance of proper cow dung management and usually resort to converting it into compost for plant biological fertilizer. However, there are numerous alternative ways to utilize cow dung waste, which can serve as a source of energy and economically valuable materials. These methods are often disregarded by the community, leading to a loss of potential benefits. According to recent research, the energy crisis in rural India can be resolved with the help of an innovative technology - the earth battery. This revolutionary battery is made from a blend of natural elements, including pure soil, cow dung, and compost. When combined, these ingredients produce a unique form of energy that can be used to power homes, farms, and small businesses in rural areas. But the benefits of the Earth battery don't stop there. This eco-friendly technology also has the potential to address the waste management challenges faced by rural communities. By using cow dung and compost as key ingredients, the battery helps to transform waste into a valuable resource, thereby reducing the environmental impact of waste disposal. Moreover, the adoption of the earth battery can help to make rural communities more economically self-sufficient. By providing a reliable source of energy, this technology can enable farmers and entrepreneurs to grow their businesses and improve their livelihoods. It can also enhance the health and well-being of rural communities, by reducing their dependence on traditional fuels which can have negative impacts on health. Overall, the earth battery has the potential to transform the lives of rural communities in India, by addressing their energy needs, reducing waste, and promoting economic development.

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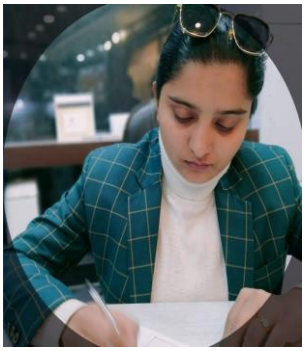
Author Profile



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ENERGY CONSERVATION: UNDERSTANDING THE ROLE OF END USER BEHAVIOR

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Abstract:
Pune's geographical boundary has increased significantly in recent years. This has led to increased energy consumption and demand. As per PMC's Environmental Status Report (ESR), power consumption in Pune has increased to 4982.9 million units in 2021-22 from 4463.59 million units in 2020-21 [1].Buildings consume a significant amount of energy, making it a prime target for application of energy efficiency measures. The cost effective and environment friendly solution for increased energy consumption is to adopt (a) Energy Conservation Measures (ECMs) and (b) Energy Efficiency (EE) Measures. Energy Efficiency (EE) involves using technology that requires less energy to perform the same function, eg: Installing LED Light fixtures. Energy Conversation Measures (ECMs) on the other hand involves reduction of energy consumption by adjusting human behaviour and habits, eg: Switching off fans, lights, and other appliances when not in use. While technical advances make it possible to improve a product's operational performance, it is the user's decision and behaviour that has a considerable impact on the product's energy consumption. The installation of energy saving technologies must be accompanied by energy-efficient occupant behaviour to ensure sustained reductions in energy consumption [8]. For understanding this, literature reviews and a small-scale live case study was conducted. The live case study required an understanding of current consumption practices in the space of the building. From its results, it was seen that there is a willingness among users to invest in conserving energy. From the literature reviews and live case study, it can be concluded that user behaviour has considerable impact on the energy consumption in a building. Increasing user's awareness towards the impacts of their own behaviour and increasing their knowledge about better behavioral alternatives is important. When the users are convinced that this type of behaviour is giving them the highest benefits (in terms of money, etc.) while simultaneously not facing extreme constraints on behaviour, it will encourage and create a pro-environmental behaviour after a certain time. It will be willingly followed if the users experience its benefits on a monthly or annual basis.

Keywords:
Energy Conservation, Energy Efficiency, Energy Consumption, User/Occupant behaviour, Pro-environmental behaviour.

1. Introduction

Pune's geographical boundary has increased significantly in recent years. This has led to increased energy consumption and demand. As per PMC's Environmental Status Report (ESR), power consumption in Pune has increased to 4982.9 million units in 2021-22 from4466.59 million units in 2020-21 **[1]**. Buildings consume a significant amount of energy, making it a prime target for application of energy efficiency measures. As per BEE (Bureau of Energy Efficiency) of India, the cost effective and environment friendly solution for increased energy consumption is to adopt:

a) Energy Conservation Measures (ECMs).
b) Energy Efficiency (EE) Measures.

Table 1: List of activities falling under ECMs and EE [4].

Energy Conservation Measures (ECMs)	Energy Efficiency (EE)
1. Switching off fans, lights, and other appliances when not in use.	1.Installing LED Bulbs which are more energy efficient.
2. Avoiding charging of electronic devices overnight to prevent wastage of energy.	2. Installing motion sensor lighting fixtures.
3. Maintaining AC Temperature at 24°C to 26°C for good health and comfort.	3.Using BEE star rated appliances.
4. Admitting natural light inside a building as much as possible to reduce use of artificial lighting during daytime.	4.Cleaning Air Conditioning Filters regularly.

From the above measures, it is evident that Energy Efficiency (EE) involves using technology that requires less energy to perform the same function, eg: Installing LED Light fixtures. Energy Conversation Measures (ECMs) on the other hand involves reduction of energy consumption by adjusting human behaviour and habits. During the design stage of buildings, energy simulation is used to predict the energy consumption of buildings. However, often times, there is a gap between the predicted and actual energy consumption. Human behaviour and occupant preferences are important contributors causing fluctuations between the predicted and actual building energy consumption. Efficiency gains will come from technical inventions in the product, but also from changes in human behaviour. The impact of building user behaviour on energy consumption is usually not considered during the design phase or the post-occupancy optimization phase **[7]**.

The purpose of this paper is to understand the impact of user behaviour on the energy performance of a building and a space in the building. In the second section, literature reviews of reports and papers with direct relevance to the subject were conducted. In the third section, a small-scale live case study was conducted to understand the consumption practices in an actual setting.

Awareness was created in the setting through posters; and results were recorded in the form of electricity bills of different months; the amount in the month where there is no awareness, and the amount in the next month after the awareness is created. The amounts of electricity bills of these months are compared in order to identify the impact of user behaviour. This is the quantification methodology that is adopted to investigate user behaviour and their impact on energy consumption. In the fourth section, conclusion and recommendations are provided.

2. Aim, Objectives, Scope and Limitations:

2.1 Aim: To understand the role of end-user behaviour in energy conservation.

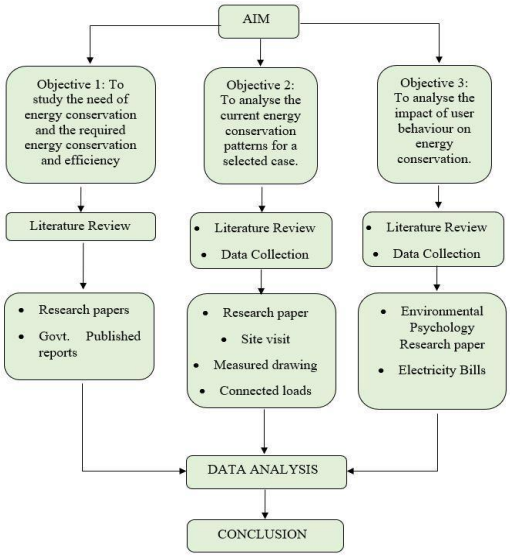
2.2 Objectives:

a. To study the need of energy conservation and the required energy conservation and efficiency measures.
b. To analyze the current energy conservation patterns for a selected case.
c. To analyze the impact of user behaviour on energy conservation.

2.3 Scope: The study will focus on how human behaviour impacts energy consumption and discusses the strategies for pro-environmental behaviour among users.

2.4 Limitations: This paper presents data on a small-scale case study. Parameters and results may differ in case of large-scale buildings.

2.5 Methodology:



F1: Methodology Flowchart

3. Literature Reviews:

3.1 In the Environmental Status Report (ESR) of Pune Municipal Corporation (PMC), information about Pune city has been provided, along with discussion on Sustainable Development Goals (SDGs). The ESR is a comprehensive document that serves as an information resource base for identification of critical issues and also as an input for new city /town Development Plans (DPs) or revisions in them. The ESR of 2021-22 is prepared using the theme of Panchatatva (The 5 elements), namely

a) Bhumi-Earth (Green cover, Biodiversity, Solid waste management, etc.)
b) Vayu-Air (Air Quality and Pollution and Solutions, Noise Pollution, etc.)
c) Jal-Water (Water supply and storage, Sewage and Waste Water Treatment, etc.)
d) Agni-Fire (Energy consumption, Carbon footprint, etc.)
e) Akash-Enhancement (City's Weather, Public Awareness, etc) **[3].**

As per the ESR, the energy consumption of Pune city has increased to 4982.9 million units in 2021-22 from 4463.59 million units in 2020-21 **[1].**

पुणे शहरातील ऊर्जा वापर

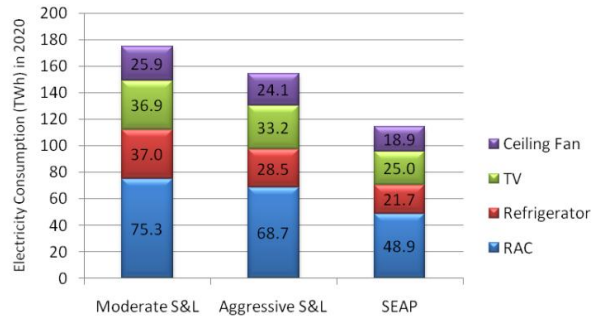
Sector	Energy Consumption (MU) Year 2020-21	Number of Consumers 2020-21
Residential	2045.81	1485998
Industrial	1146.83	19427
Commercial	743.56	203964
Others	261.15	95075
Municipal	252.18	3072
Agriculture	14.06	1296
Total	4463.59	1808832

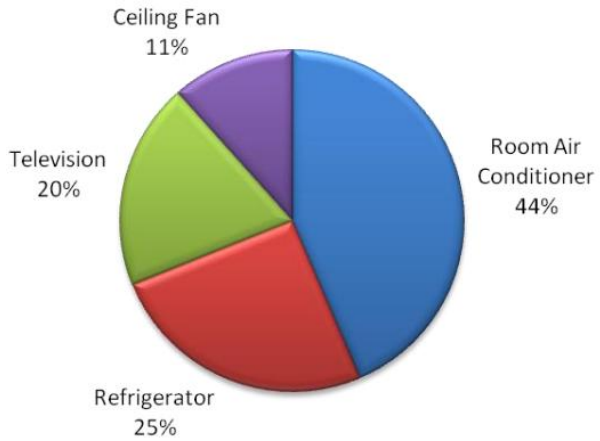
F2: Energy consumption of Pune City [4].

3.2 In their study, Prayas Energy Group from Pune state that there is an urgent need to go beyond India's current Standard and Labelling (S&L) program by BEE

(Bureau of Energy Efficiency) for electrical appliances. The rating is given in the form of stars (1 star-least efficient, to 5 star-most efficient). They present a case for promoting super-efficient appliances (SEA), which are even more efficient than 5-star rated appliances in India. However, the SEAs are mostly international models and the market shift in India is difficult due to expensive models, reservations of the manufacturers, etc. For conducting the study, four types of electrical appliances, namely room air conditioners, refrigerators, television sets, and ceiling fans were considered and the electricity consumption was estimated under three scenarios, namely Moderate S&L promotion, Aggressive S&L promotion, and Super-Efficient Appliances Program (SEAP). The savings were then calculated as the difference in consumption between the scenarios **[6].**

From the study, it was concluded that, the consumption in the SEAP scenario is about 115 TWh as compared to 154 TWh in the Aggressive S&L scenario and 175 TWh in the Moderate S&L scenario. Total savings due to the shift to SEA over the Moderate S&L scenario are approximately 60 TWh by 2020, three times as much as those in the Aggressive S&L scenario **[6].**





F3(a) & 3(b): Contribution of different categories of SEA to annual savings in 2020 [6].

3.3 Robert Gifford, Linda Steg, and Joseph P. Reser in their paper 'Environmental Psychology', discuss the impacts of human behaviour on the environmental quality around them. Environmental psychology is the study of transactions between individuals and their physical settings (Gifford, 2007a) and includes theory, research, and practice aimed at making the built environment more humane and improving human relations with the natural environment. The paper states the factors upon which human behaviour is influenced and supports it with psychological theories. It also provides interventions and strategies that can be used to cultivate pro-environmental behaviour patterns within human beings.

3.4

3.5 The paper states that when users are better informed and aware about the impacts of their behaviour on the environment, it may strengthen their commitment to change their behaviour, and to maintain the changes realized. It is also important to educate them about behavioural alternatives and their pros and cons. The paper recommends that policies to be implemented for pro-environmental behaviour will be more acceptable, when they are believed to be fairer, when they are effective in reducing relevant problems, and when they do not seriously affect individual freedom or put severe constraints on their behaviour **[5]**.

3.6 In their study, Antonio Paone and Jean-Philippe Bacher from Switzerland **[7]** state that user behaviour can increase the efficiency of the energy used in the building and studies the impact of occupant behaviour on different building typologies through literature reviews and case studies. The human decision-making process and its influence on energy is also discussed where it is concluded that consumers' decisions depend on the manner the information is presented to them. Introducing the decision as a choice between losses or gains, different outcomes may be attained. Since occupants do not always make consistent rational decisions, the manner of presenting the choice itself becomes determinant in order to adopt energy-efficient behaviours. It further states that adaptive behaviours are fundamental in order to foster energy efficiency, but any unacceptable degree of user satisfaction or discomfort has to be avoided in order to do not generate counterproductive behaviours. If the decisions about environmental adjustments such as window opening, blind positioning, fan on/off, and thermostat up/down, etc. cannot be made by occupants, occupant comfort perception is negatively affected because they have less control over their environment.

The paper recommends strategies that influence building occupant behaviour that are discussed are as follows:

a) Eco-feedback: An eco-feedback system provides building occupants with information regarding their historical and current energy consumption levels for motivating energy-efficient behaviour. Since scientific energy units, such as kWh and CO2 emissions, are difficult to comprehend by users, providing feedback in terms of a tangible units,

such as "trees or stars", may increase user comprehension and energy savings. Usually a web-based energy dashboard is used as interface between users and eco-feedback to self-monitoring and comparison purposes. Adding advices and tips on the dashboard has been reported to be an effective way to improve the impact of eco-feedback.

b) Gamification: Games enable interactive experiences that exploit several sub-processes that govern observational learning. Games encourage new behaviours by suggesting appropriate actions and provide motivation for tangible and social actions. However, the examples and studies are rare so far and requires more research.

c) Social Interaction: Several studies have incorporated a normative comparison (user ranking) component within an eco-feedback system that allows users to compare their energy usage with their peers and neighbours. Studies revealed that normative feedback is more effective than purely historical feedback in energy use reductions and yielding energy savings. A positive correlation is observed between the social position of a user in the network, as well as the number of social connections of a user and the amount of energy they conserved **[7].**

4. ABOUT ENVIRONMENTAL PSYCHOLOGY:

In their paper, 'Environmental Psychology', Robert Gifford, Linda Steg, and Joseph P. Reser discuss the impacts of human behaviour on the environmental quality around them. Environmental psychology is the study of transactions between individuals and their physical settings (Gifford, 2007a) and includes theory, research, and practice aimed at making the built environment more humane and improving human relations with the natural environment.

According to the paper, many environmental problems are rooted in human behaviour. Improving environmental quality via behaviour changes will be more effective when one (1) selects behaviour that significantly affects environmental quality, (2) examines which factors cause those behaviours, and (3) applies and evaluates interventions that change these antecedents and the behaviour (Geller, 2002; Steg &Vlek, 2009). In order to decide which factors should be targeted to encourage pro-environmental actions, one needs to understand which factors promote or inhibit pro-environmental behaviour. The factors studied are as follows:

a) Motivational factors: Cost -benefit deliberations, and normative concerns. The theory of planned behaviour (TPB; Ajzen, 1991) assumes that individuals choose alternatives with highest benefits against lowest costs (e.g., in terms of money, effort, and/or social approval). The norm - activation model (NAM; Schwartz, 1977) and the value - belief - norm theory (VBN theory; Stern, 2000) assume that people act pro-environmentally when they feel a moral obligation to do so, which depends on the extent to which people are aware of the problems caused by their behaviour, and feel responsible for these problems and their solution. VBN theory further proposes that problem awareness is rooted in environmental concern and values. However, in situations characterized by high behavioural costs or strong constraints on behaviour, such as reducing car use, their explanatory power is generally low (e.g., Bamberg &Schmidt, 2003).

In the live case study conducted, the users were made aware of the manner in which the wastage of energy was taking place, and were presented with solutions that could lead to energy conservation.

b) Contextual factors: Many contextual factors may facilitate or constrain environmental behaviour and influence individual motivations, such as the availability of recycling facilities, or the quality of public transport (e.g., Ölander &Thøgersen, 1995).

In case of interventions, various strategies for behaviour change have been identified, each focusing on a different set of behavioural determinants.

a) Informational strategies- These can be aimed to increase user's awareness of environmental problems and to increase their knowledge of behavioural alternatives and their pros and cons. Informational strategies in themselves are especially effective when the pro-environmental behaviour is not very costly, and when individuals do not face severe external constraints on behaviour.

In the live case study conducted, attempt was made to increase the user's awareness by providing them the information regarding the current energy consumption through electricity bills.

b) Structural strategies-They either aim to reward approved behaviour, or punish disapproved behaviour. When rewards and penalties are strong, people can attribute their behaviour change to the incentive and not to their personal convictions.

Environmental psychologists have an important role to play in the management of environmental problems through the promotion of behaviour change. Behavioural interventions are generally more effective when they are systematically planned, implemented, and evaluated. Individuals can contribute significantly to achieving

long - term environmental sustainability by adopting pro-environmental behaviour patterns. The challenge for environmental psychologists is to understand the individual and structural factors and processes that

threaten environmental sustainability, so that pro-environmental behaviours can be facilitated worldwide.

5. Live Case Study:

A small-scale live case study was conducted at a hostel in Katraj, Pune. It was observed that the lights in the common area were being kept switched on during night-time, even when the space is not occupied by the residents. An attempt was made to spread awareness and change residents' behaviours by installing posters in the common areas that requests them to switch on the lights when they enter the space and switching them off when they leave the space. Results were collected in the form of electricity bills of the months where there is no awareness and the month after the awareness has been spread. From the electricity billing history, it is evident that the amount decreases from the month of November, after the intervention was made in the previous month, appealing the residents cautiously consume electricity.

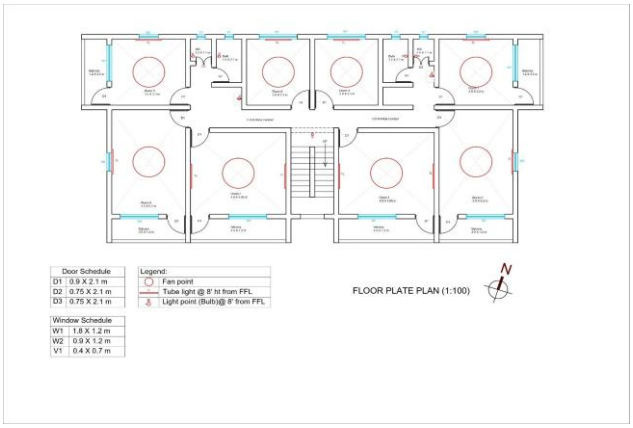
The Theory of Planned Behaviour (TBP) and Value-Belief- Norm theory (VBN Theory) has been used here as a motivational factor, along with an Informational type of Strategy in order to achieve the result.

5.1 Location:

The hostel building is located in Katraj, Pune, Maharashtra, India.

F4(a) & 4(b): Location of Hostel Building

5.2 Floor plans and Connected load calculations:



F 5: Floor plate plan of the hostel.

F6: Picture of common area (Bathroom)

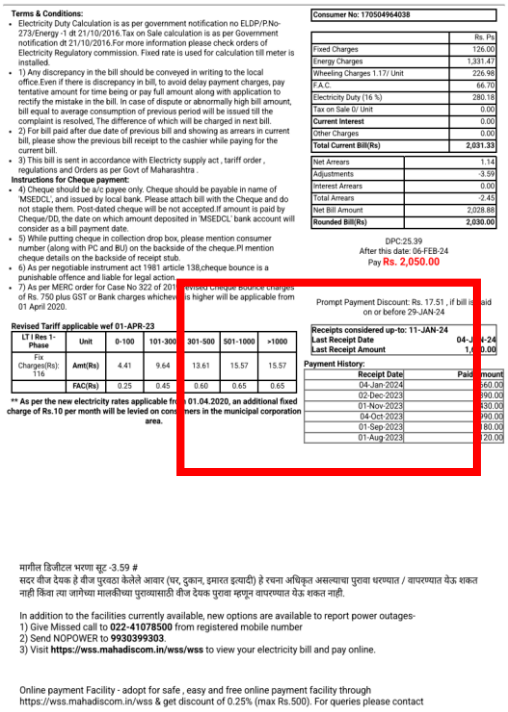
F7: Picture of common area (Washbasin) with Location of poster

F8: Picture of Bulb used in common areas

Table 2: Connected Load Calculations.

Connected Load for the Hostel Floor							References
Floor	Type of Light	Nos.	Working Hours	Wattage	Connected Load (Nos. X Wattage)	Total Wh/Day (Connected load X Working hrs.)	
Hostel Floor	LED Tube light	10	8	20	200	1600	[9], [10]
	LED Bulb	7	8	5	35	280	
	Fans	8	12	48	384	4608	[2]
			TOTAL	73	619	6488	

5.3 Electricity Bill:

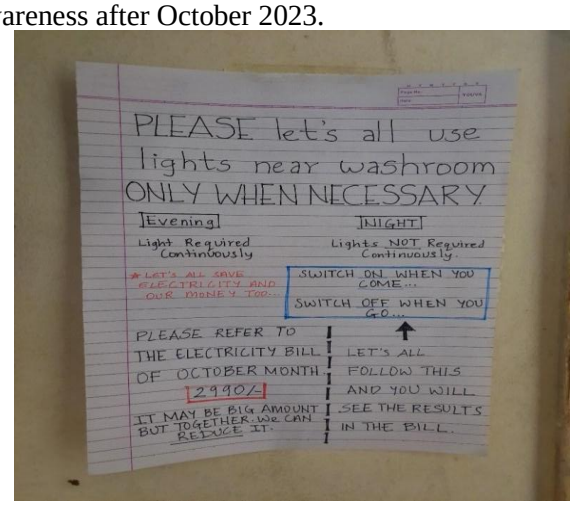


F10: Electricity Bill with billing history highlighted.

From the billing history highlighted in the bill above, it is seen that the energy consumption is increased significantly in the month of October.

5.4 Measures implemented to change user behaviour:

Posters were installed near common areas to spread awareness after October 2023.



F11: Picture of Poster in common area

5.5 Impact:

The impact of the posters and user behaviour in response to it impacted the electricity bill. It is evident from the billing history that the prices to be paid for electricity bills reduced in the month of and after November 2023.

Receipts considered up-to: 11-JAN-24	
Last Receipt Date	**04-JAN-24**
Last Receipt Amount	**1,660.00**

Payment History:

Receipt Date	Paid Amount
04-Jan-2024	1,660.00
02-Dec-2023	2,390.00
01-Nov-2023	2,430.00
04-Oct-2023	2,990.00
01-Sep-2023	2,180.00
01-Aug-2023	2,120.00

Figure 12: *Billing History indicating a drop in the amount from November 2023.*

6. Conclusions And Recommendations:

From the literature reviews and live case study, it is evident that user behaviour impacts energy consumption. From the literature reviews and payment history of electricity bills in the case study, it can be concluded that user behaviour has considerable impact on the energy consumption in a building. Increasing user's awareness towards the impacts of their own behaviour and increasing their knowledge about better behavioral alternatives is important. When the users are convinced that this type of behaviour is giving them the highest benefits (in terms of money, etc) while simultaneously not facing extreme constraints on behaviour, will encourage and create a pro-environmental behaviour after a certain time.

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The prominence of the courtyard for classroom lighting and acoustics – A case of an institutional building

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Abstract:
The courtyard is a design element suitable for all types of buildings in different climatic zones, acting as a buffer zone to control unwanted sound and providing daylight for visual comfort. In the design of institutional buildings, various aspects such as the incorporation of proper lighting levels and a comfortable environment to perform tasks are important. This paper focuses on the role of courtyards in institutional buildings, specifically regarding classrooms, to control noise and achieve visual comfort. The methodology includes a literature review and a field survey of selected cases. The field survey comprises the documentation of data available through observation and field measurements using calibrated instruments. Analysis of the documented data is conducted to reach results and conclusions. From the study, it is concluded that the integration of courtyards in core spaces of institutional buildings helps enhance daylighting for visual comfort, energy savings, and acoustical environments.

Keywords:
Buffer, Courtyard, Daylighting, Illumination levels, Sound attenuation.

Introduction

The courtyard as a design element has been used in buildings for ages. There are numerous benefits associated with courtyards. It introduces daylight and helps to create a visual connection between the spaces. The spaces connected to the courtyard get a sense of openness and have a direct impact on the work atmosphere of the space.

Courtyards are classified concerning size, shape, and depth. The size of the courtyard should be such that it provides proper light and ventilation to the spaces surrounding it. Courtyards play an important role in guiding sun and wind movements. Integration of the courtyard helps to enhance the environmental quality of internal spaces. To achieve a good productive outcome, the indoor environment about the availability of daylight, the acoustical environment, and air movement in the spaces play an important role. In institutional buildings, the conduction of various teaching and learning activities takes place. For this purpose, the proper location of the courtyard in accordance with the immediate surrounding spaces plays a major role.

The paper emphasizes the contribution of the courtyard in the institutional built environment concerning three aspects.

- Daylighting
- Sound attenuation
-

1.1 Daylighting

Daylighting aims to increase natural light inside the building for uniform light. (Strobach & Boriskina, 2018).

Le Corbusier once stated that
“Light creates ambiance and feel of a place, as well as the expression of a structure.”

Daylighting is an essential parameter in the design of the indoor built environment that plays an important role in enhancing the quality of spaces. The admittance of light is influenced by the organization of spaces, the geometry of spaces, and reflections from surrounding built envelopes

along with their colours and textures. Without appropriate lighting levels, occupants cannot fulfill their activities efficient and effective manner.

Daylight is used in buildings by occupants to perform various activities. As it is a free source of light it can be introduced into spaces to save energy and attain visual comfort. Recommended Lighting Levels for classrooms are 300 - 500 lux as per the Illuminating Engineering Society of North America (IESNA) and 200-500 lux as per the National Lighting Code of India. Daylighting for core spaces in institutional buildings can be aided by the incorporation of a courtyard as a design element. Direct light penetration creates glare and affects the thermal comfort of the space. The

courtyard helps to avoid glare and provides lighting levels to perform visual tasks with a reduction in energy usage for the creation of a better environment.

1.2 Sound attenuation

In institutional building, formal education takes place in the classroom. Appropriate environment for teaching and learning activities is essential (Jolly, Thampuran, & Premlet, 2015). The productivity of the educational environment also depends on the acoustical conditions of the classrooms. The suggested noise criteria range for classrooms is 40-45 dB.

Excessive noise creates an uncomfortable learning environment. It is a prime factor to attenuate unwanted sound by building design elements. A courtyard is a space that can separate spaces to reduce unwanted sound. The landscaping features in the courtyard also contribute to attenuating unwanted sounds. Sound reflection can be reduced through the integration of vegetation in the courtyard which is by segregating the spaces.

The thick growth of leafy trees and underbrush reduces noise by about 6 to 7 dB /100 FT (average over audible frequency range). Low-frequency loss - 3 to 4 dB, High-frequency loss - 10 to 12 dB **(**Stein & Reynolds, 1999).

1.3 The objective of this paper is

- To identify the role of the courtyard in providing daylighting and a well-acoustical environment in the classrooms.
- To recognize the role of the landscaping elements within the courtyard..

1.4 Scope

The study focused on the role of the courtyard in an institutional building only for the availability of daylight, and classroom acoustics for warm and humid climate zone.

1.5 Research question

How does the courtyard concerning its size and features affect the lighting and acoustical environment for the adjacent classrooms?

2. Literature review

The configuration of the courtyard in the building offers more daylight. (Guedouh, Zemmouri, & Assassi, 2017). The unwanted sound is reduced by vegetation through reflection, refraction, absorption, and diffraction (Zhu, Jiani, Fan, & Zhiyi, 2010). When sound travels on vegetation the sound is attenuated by absorption on the surface of tree leaves. The total sound attenuation by vegetation is changed depending on the directions of sound travel (Watanabe & Yamada, 1996).

Relatively better indoor thermal modification is seen when the courtyard acts as an air funnel discharging indoor air into the sky, rather than the courtyard acting as a suction zone inducing air from its sky opening, as suggested by conventional knowledge.

A courtyard offers greater flexibility in helping larger areas of internal spaces, which benefit from ventilation and daylighting (Kenneth & Napoleon, 2019).

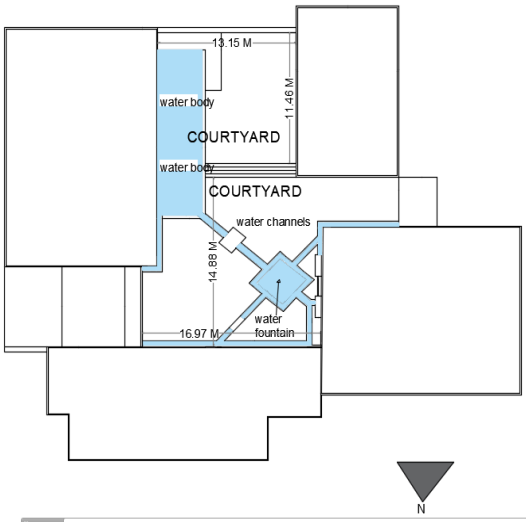
3. Methodology

The method adopted for the research paper is data in the form of literature and live case studies of institutional buildings. Selected case studies are from Pune in a moderate climate zone. The field study is undertaken for the available illumination and sound attenuation by distance, due to the vegetation, courtyard as buffer space, and masking of unwanted sound. Data analysis is done based on the field survey measurement. Based on collected data from the literature review and case study analysis, a conclusion has been drawn on how courtyards can play a role in enhancing daylight and acoustical environments.

4. Case studies

4.1 Case study - 1

The analysis of selected cases focuses on two parameters: availability of daylight and sound attenuation. The first case selected for analysis is the Institute of Environment Education and Research which is located in Pune. The building is equipped with a wide courtyard connected with classrooms as shown in Figure 1.

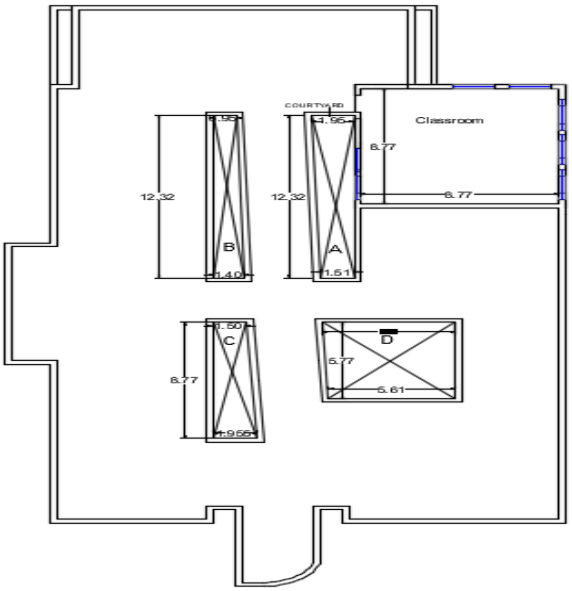


F1: Sketch Plan showing the courtyard in the Institute of Environment Education and Research, Pune.

The courtyard is designed with proper landscaping elements including water bodies, water fountains and water channels, and light-colored tiles for flooring. The building envelope is made of stone material with light color. This helps to introduce reflected diffuse light into the adjoining spaces and to control direct light from the east and west sides. The classroom windows facing towards the courtyard are on the east side.

4.2 Case study – 2

The second case selected for analysis is the Institute of Information Technology and Biotechnology which is located in Pune. The building has four different courtyards shown in Figure 2 namely A, B, C, and D. The Courtyard denoted as A is connected to the classroom which is a narrow courtyard compared to case 1.



F2: - Sketch Plan showing the courtyard in the Institute of Information Technology and Biotechnology, Pune.

5. Results and findings

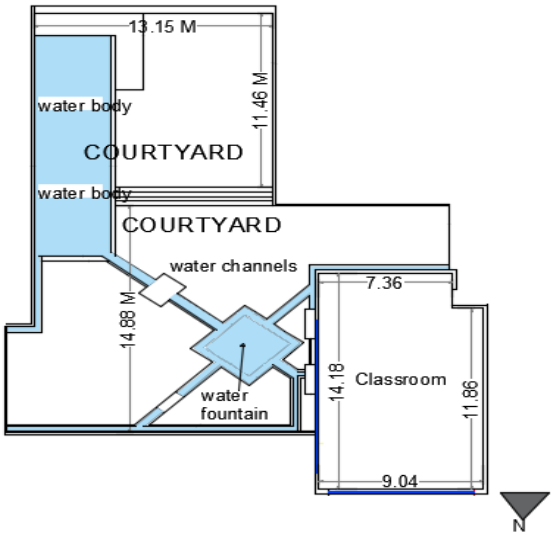
5.1 Illumination levels in the classroom based on the field measurements

The field study of available illumination levels was conducted during the overcast sky conditions. The overcast sky condition is critical sky condition for the availability of daylight as it changes the light that comes inside the space. The classrooms are deeper spaces with visual tasks. The integration of diffuse light from the courtyards is an added advantage to the daylight entering the space.

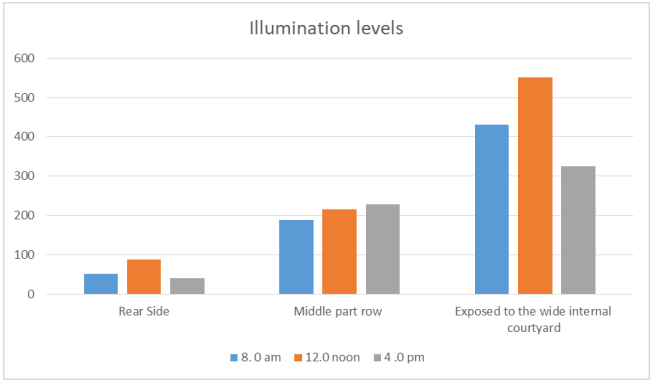
A lux meter was used to take field measurements of classrooms for three points. Illumination levels were noted for three timings of the day 8.00 am, 12.00noon and 4.00 pm.

Case study 1

In the first case, the selected classroom windows were facing towards the courtyard and were in the north direction. The courtyard was designed with light-colored tiles and water bodies that helped to filter light.



F3- Sketch Plan showing courtyard in relation to classroom



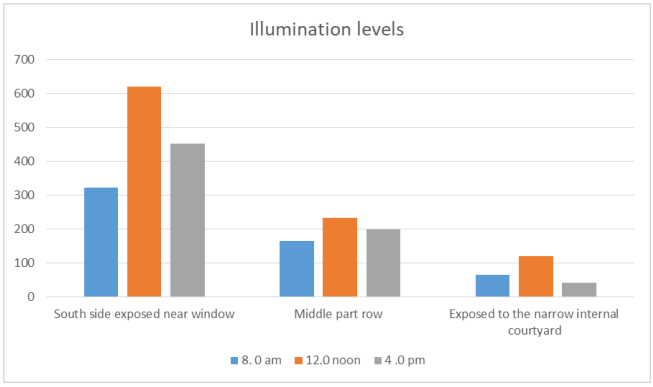
Graph 1 – Representing classroom illumination levels.

Based on the field measurement, it is seen that the illumination levels are enhanced towards the exposed wide internal courtyard side.

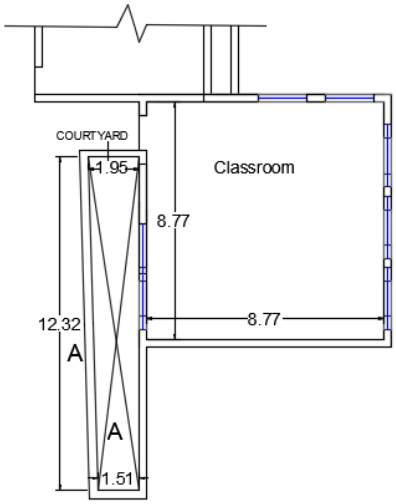
Case study 2

In the second case classroom one external wall was exposed
to the south side and the opposite wall was exposed to the narrow courtyard.

Based on the field measurement, it is seen that the illumination levels are less towards the exposed narrow internal courtyard side.



Graph 2 - Representing classroom illumination



F4 - Sketch Plan showing courtyard in relation to classroom

5.2 Sound levels in the classroom based on the field measurements

Case Study 1

The noisy area near the classroom was the auditorium. The level of sound at the source was 85 to 88 dB the courtyard between the class and auditorium acted as a buffer space. The courtyard was wide with a water fountain and vegetation. The recorded courtyard sound level was reduced to 60 to 63 dB further, it is reduced by distance and sound absorption by the surfaces within the courtyard. The sound level recorded outside the classroom was 53-56 dB the building envelope exposed towards the courtyard side was a massive wall with glass. The sound levels recorded in the classroom based on the actual reading were as follows.

Case study 2

The building comprised three enclosed courtyards and had vertical zoning to segregate the noisy and calm areas. The unwanted sound attenuation took place by distance as well as horizontal barriers in the form of building components. The courtyard was narrow with less width as shown in Figure 2.

6. Conclusion

The daylighting and acoustical environment are significant factors that need to be taken care of in the first design phase.

Based on the visual observation from the field visit, it was seen that the courtyard elements contribute to filtering the light to reduce glare into the surrounding classrooms. A courtyard with light-colored tiles reflects light into the spaces. Integration of the courtyard helps to enhance diffused daylight when spaces are deeper. In institutional buildings, there are noisy spaces and calm spaces. Both kinds of spaces are important while zoning the spaces based on their tasks and their requirement of sound levels. Based on the sound level reading, the courtyard can help to zone noisy and calm spaces separately. A wider courtyard is more effective to attenuate sound by distance when compared with a narrow courtyard**.**

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Rejuvenating River Ghats for Sustainable Development - Establishing the Land-Water Connect

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Abstract:
The impacts of modernization have led to a neglect of the natural environment resulting in the deterioration of river ecosystems and their associated cultural and spiritual significance in many societies. This paper explores the historical and cultural significance of ghats, big and small, known and unknown, their traditional role, modernisation of the cities, redundancy of the ghats in the changed urban scenario leading to the steps taken to modernise riverfronts, and the subsequent disconnect between people, communities and their cultural disconnect with the rivers that flowed through the human habitations. The creation of ghats along rivers was initially an expression of cultural coexistence, spiritual reverence and served as vital public spaces active with communal, cultural, economic and physical daily and religious activities. With urbanisation and industrialization, these ghats have faced neglect and deterioration, leading to a disconnection of the human association with water. As a result, the traditional, cultural and spiritual significance of these sites have been eroded, impacting the well-being of communities and the health of river ecosystems. The paper attempts to examine sustainable approaches to rejuvenating ghats and re-establishing the historical and cultural link between societies and settlements and rivers. It discusses the requirement and importance for holistic rejuvenation strategies that incorporate ecological restoration, cultural preservation, and community engagement. These strategies involve community-led restoration efforts, and the integration of traditional knowledge with modern technology. By revitalizing ghats through sustainable approaches, communities can once again form a meaningful association with their rivers, addressing the adverse impacts of urbanisation and promoting a healthier and more holistic relationship between people and their natural environments.

Keywords:
River Ghats, Revitalisation, Restoration, River Ecosystem, Urban Transformation

Introduction

Water is a way of life and it remains intervened with our lives in more ways than one even in Contemporary urban scenarios. The success of River Valley Civilisations established a unique bond of Human settlements and rivers passing through or along, as the geography permitted. Over the period of time, with the advancement of a civilised society, a large number of activities evolved in association to the river duly acknowledging its significance. Access to the river waters from surrounding lands was thus a very important consideration and a necessity for all the activities.

The designing and construction of Ghats for all possible social – cultural – religious reasons added a completely new perspective to the treatment of this transition, between the land and the river, between the water edge and the waters. Access to the flowing lifeline was ensured through the 'Ghats', the alternating construction of steps and landings leading to the waters from land.

In ancient times, river Ghats held significant cultural, social, religious, and practical importance in many civilizations, particularly in regions where rivers played a crucial role in daily life. River Ghats was often considered sacred places in many cultures. They served as sites for religious rituals, ceremonies, and offerings. In Hinduism, for example, Ghats along rivers like the Ganges are believed to have purifying properties, and people would bathe in the river to cleanse themselves of sins. These Ghats were also where cremation ceremonies took place, symbolizing the cycle of life and death.

The River Ghats were integral parts of the historical and cultural heritage of various civilizations. They have witnessed centuries of human activities, traditions, and rituals, preserving the collective memory of communities living along the rivers. Many ancient Ghats continue to be revered as symbols of tradition and continuity, attracting pilgrims, tourists, and researchers interested in exploring their rich heritage.

The River Ghats were important social hubs where people gathered for various activities. They served as meeting points for communities, providing spaces for social interactions, trade, and commerce. Along with religious activities, Ghats were often venues for festivals, markets, and cultural events, fostering a sense of community and connectivity. They also played a crucial role for practical purposes such as bathing, washing clothes, and fetching water. They provided access to the river for daily activities, ensuring a reliable water source for communities living along the riverbanks. Additionally, Ghats served as docking

points for boats and ferries, facilitating transportation and trade along river routes.
Overall, river Ghats played multifaceted roles in ancient times, serving as centres of religious devotion, social interaction, economic activity, and architectural splendour, while also embodying the historical and cultural legacies of the civilizations that thrived along the riverbanks.

Rivers in Urban Areas today:
In modern times, several challenges have emerged that have impacted Rivers and their Ghats in various ways and made them irrelevant infrastructure. The speedy transformation of the cultural society to a cosmopolitan society and the drastic pace of urbanisation have completely changed the lifestyle, infrastructure facilities and the standard of living. This has completely changed the perspective of looking at the river, reducing it an obsolete geographical asset. The drying and channelization of the river have also ripped them off from their local beauty. Misuse, bad maintenance, changed concepts of open spaces have made these amazing manifestations of architectural heritage into ignored land uses in Urban cities.

Addressing these issues requires concerted efforts from all stakeholders like governments, communities, planners and users to ensure the preservation, restoration, and sustainable management of river Ghats. It is very important that these Urban liabilities be converted to Urban assets for the citizens of the city. Most of the cities with rivers have ghats constructed on them however they are not in use due to the status of the river. Revitalising the ghats and the areas around them can play a major role in reviving the Land water connect in the urban areas also enhancing the quality of the rivers passing through the cities.

This may involve implementing pollution control measures, enforcing regulations to prevent encroachment, investing in infrastructure maintenance and repair, promoting community engagement and awareness, and integrating climate resilience strategies into riverbank management plans.

F1: Krishna Ghat, Wai

What is Revitalisation?
Revitalization refers to the process of restoring vitality, energy, or vigour to an area, organisation, system, community, or environment that has experienced decline or stagnation. This typically involves initiatives and strategies aimed at enhancing and renewing the economic, social, cultural, or physical aspects of the target area or entity. Revitalization efforts often encompass revitalising urban neighbourhoods, business districts, historic areas, or natural landscapes through urban renewal, economic development, community engagement, and other revitalization tactics. The goal of revitalization is to stimulate growth, improve liveability, and promote sustainability, ultimately leading to a restored and thriving condition.

What has changed with the rivers over a period of time?
One of the most significant problems facing the Urban Rivers and the River Ghats in modern times

- The role of the river in the city as ‘Giver’ has changed to ‘Taker’ with the modernisation and urbanisation of cities.
- The unbalanced and haphazard growth have pushed the rivers into the backyards of the development. The rivers have fallen to unuse and misuse over the years, they no longer being the source of daily waters visited to be fetched.
- Industrial waste, agricultural runoff, untreated sewage, and plastic pollution are being emptied into the rivers severely degrading water quality
- River ecosystems are fast being deleted and destroyed with no regards to its consequence.
- The Spiritual and aesthetic appeal of the Ghats is fast diminishing, making them less inviting for religious rituals and socio-cultural activities.
- Access to the waters by ghats are put to misuse deterring people's connections to the flowing waters further adding to the grim situation.

Situation of River Ghats in an Urban Area
Urban river ghats encounter a multitude of concerns arising from fast urbanisation and inadequate infrastructure. One major problem is pollution, which puts human and aquatic life at risk due to the frequent contamination of these water bodies by sewage, industrial runoff, and urban runoff. The capacity of ghats to hold ceremonies, meetings, and leisure activities is diminished due to encroachment and illegal construction along the riverbanks. Furthermore, improper waste management makes littering and rubbish buildup worse, which worsens the ghats' aesthetic and environmental qualities. Defecation in the open is a result of inadequate sanitation facilities, which further contaminates the surrounding water and environment.

River ghats are also affected by erosion and sedimentation, resulting in structural damage and instability. These problems are made worse by climate change, which alters water flow patterns and increases flooding. Moreover, the degradation of ghats is accelerated by neglect and poor upkeep, diminishing their historical and cultural relevance.

1. Pollution in the river - Indrayani River

Alandi is located on the bank of the Indrayani River, 18.8 km from Khed Taluka of Pune District, near the northern edge of the city of Pune in the state of Maharashtra, India. The town is popular as a place of pilgrimage and the resting place of the 13th century Marathi saint Sant Dnyaneshwar.
Alandi. Every year, the Paduka (symbolic sandals) of Dnyaneshwar go on a 21-day Palkhi from Alandi to reach Pandharpur on Ashadhi Ekadashi (June or July in the Gregorian calendar). The Palkhi procession is joined by thousands of Varkari devotees for the 150 km journey.

The Indrayani River originates in Kurvande village near Lonavla, a hill station in the Sahyadri mountains of Maharashtra, India. Fed by rain, it flows east from there to meet the Bhima River, through the Hindu pilgrimage centers of Dehu and Alandi. It follows a course mostly north of the city of Pune. It is revered as a holy river and is associated with religious figures such as Sant Tukaram and Dnyaneshwar. Originating from the Western Ghats, River Indrayani, travels a total distance of 92.2 km, of which 20.6 km falls in the city of Pimpri Chinchwad, formerly a fringe area of Pune, and now a rapidly urbanising city.
There are 6 ghats in Alandi - Indrayani River Ghat, Alandi Dhobi Ghat, Pundalik Ghat, Dashkriya Ghat, Vishwa Shanti Kendra Ghat and Shree Saint Dnyaneshwar temple Ghat.[1]

“The main cause of pollution of Indrayani River ghat is the mixing of treated, semi-treated and untreated domestic sewage from local bodies released into the Indrayani River through various drains, The toxic foam is the result of untreated effluents released by industries. Due to which fish dies off in the river over the past few years. Bathing **ghat** on banks of the **Indrayani** River. People bring ashes of relatives to be ceremoniously immer. The locals further alleged that due to pollution they are forced to stop their daily rituals as it is causing them many skin diseases.” [2]

F2: Present appearances of Indrayani River Ghat, Alandi

The pollution in the Indrayani River underscores a critical urban issue. Rapid urbanisation has led to unchecked industrial discharge, sewage, and waste dumping into the river, severely contaminating its waters. This not only threatens aquatic life but also jeopardises the health and well-being of urban communities dependent on the river for various purposes.

2. Urbanisation and encroachment, Garbage and Filthy areas - Nag River, Nagpur

Nagpur is the third-largest city of the Indian state of Maharashtra after Mumbai and Pune. Known as the "Orange City". It is also called the Tiger Capital of India or the Tiger Gateway of India as many tiger reserves are located in and around the city, Nagpur is the 13th largest city in India by population.

Nag River acts as the storm water drainage for west (part), south, central & east Nagpur. Total length of Nag River is 17.00 Km up to the city limit. Its width ranges from 12 to 40 m and depth varies from 2 to 4.5 m. Total length of Nag River up to the confluence with Kanhan River at Agargaon is about 68 Km. Nag River is polluted due to untreated sewage, industrial effluent and indiscriminate solid waste. According to MPCB river water quality is not highly polluted and can sustain fishes etc.(Mudholkar, 2018)

F3: Present appearance of Sangam Ghat, Nagpur

"There are no such holy ghats in Nagpur along the Nag river. Although, the ghats which are present in the city are only Dahan Ghat, they are - Besa Ghat and Nara Ghat.
One of the holy ghat in Nagpur is Sangam Ghat near Sangameshwar temple. With increase in human settlement along the banks and many sewer lines discharging in it, Nag River is polluted to a dangerous extent. Encroachments on the banks have further complicated the situation." [4]

The Sangam Chawl in Sitabuldi is home to some of the city's heritage temples, including over 200 years old structures like the Karthikeya, Shiva, Hanuman and Krishna temples. Originally owned by King Bhosale, the land was given to the late Congress member Binnu Pandey for upkeep. However, some of them have become hangout spots for antisocial elements while some have been turned into residences (illegally) by occupants over the last 3 generations. In earlier times, worship was the only reason people visited the temples. It is now difficult to maintain the property free of antisocial characters. (In an interview with temples priest Mr. Tiwari)

The pollution in Nag River epitomises an acute urban concern. The river's ecology has been seriously harmed by uncontrolled industrial effluents, sewage discharge, and trash disposal brought on by rapid urban expansion. This represents structural environmental mismanagement in urban areas and endangers the livelihoods and health of urban residents who depend on the river.

3. Loss of cultural activity / Depletion of Sacred Places

Krishna river Wai
Wai is a town in Satara district of Maharashtra state in India. Located on the Krishna River, Wai was a prominent town during the Peshwa era.
The river, also called Krishnaveni, is 1,400 kilometers long and its length in Maharashtra is 282 kilometers. It is a major source of irrigation in the Indian states of Maharashtra, Karnataka, Telangana and Andhra Pradesh.

Krishnamai festival at Wai, Maharashtra
The town of Wai continues its river festival, which is unique for its spatial richness. It survives as a continuous cultural tradition in which both the tangible and the intangible can be experienced. The festival converts a semi-private event, celebrated in the house with relatives and neighbours into an urban festival aimed both at devotion and at community bonding.

The Krishnamai festival began when Shendye Shāstri of Wai prayed to the Krishna River for Chhatrapati Shivaji Maharaj's success when warlord Afzal Khan came out from Wai to attempt to fight him. Every ghat celebrates it for four to eight days.

With the passage of time, however, the connection between the river and its festival has weakened. The river has become a flowing sewer, carrying wastewater from the town. Lack of sewage treatment and regular maintenance has made the river a stinking and stagnant trickle of water. (Sahasrabudhe & Kashyap, 2016)

The pollution in the Krishna River at Wai underscores a pressing urban challenge. The river has been contaminated by rubbish dumping, sewage discharge, as a result of uncontrolled urban growth. This demonstrates urban environmental mismanagement by threatening the ecosystem's health and the quality of the water.

F4: Present appearances of Ganpati Ghat, Wai

Ganapati Immersion into the River
Ganpati immersion rituals, marked by the release of idols into water bodies, contribute significantly to pollution. The materials used in idol construction, such as plaster of Paris and toxic paints, contaminate aquatic ecosystems. Additionally, overcrowding at sacred sites during these events leads to environmental degradation and threatens the sanctity of these revered places.

4. Changed land uses on the river banks and Channelised waters - Mutha river, Pune

"Pune is a sprawling city in the western Indian state of Maharashtra. It was once the base of the Peshwas (prime ministers) of the Maratha Empire, which lasted from 1674 to 1818. The Mutha River is a river in western Maharashtra, India. It arises in the Western Ghats and flows eastward until it merges with the Mula River in the city of Pune. It has been dammed twice, first at the Panshet Dam, used as a source of drinking water and irrigation for Pune city. The length of Mutha River is 10.4 kms. The civic body has constructed many cement river banks, which have disturbed the natural flow of the river. The pollution in the river is

also due to mixing non-treated sewage water into the river basin. Also, many industrial units are diverting their pollutants to water bodies, which increases river pollution." [1]

The pollution in the Mutha River epitomizes a critical urban dilemma. Uncontrolled urbanization has resulted in sewage overflow, and indiscriminate waste disposal, severely contaminating the river. This endangers human as well as aquatic life, compromises water quality, and threatens the health of urban residents reliant on the river.
The channelization of rivers has brought about significant alterations in land use along their banks. Once meandering natural watercourses, now confined within artificial channels, have spurred intensive human activities. Agricultural lands have expanded closer to the riverbanks, benefiting from controlled irrigation. In earlier days river ghats had temple premises but now urbanization has flourished with the assurance of flood control, leading to the establishment of residential and commercial areas along with vehicular roads besides the river. However, this alteration often disrupts natural habitats as well as deplete water quality, increases flood risk downstream, and exacerbates erosion. Consequently, the delicate balance between human needs and environmental sustainability demands meticulous planning and management of land use along channelized river corridors.

5. Ignored Heritage - Ghorpade ghat, Pune

In some cases, river Ghats have suffered from neglect and lack of maintenance by authorities. As a result, essential infrastructure such as steps, platforms, and bathing areas may fall into disrepair, making it difficult for people to access the river for religious or practical purposes. Additionally, inadequate waste management and sanitation facilities can further contribute to the degradation of Ghats.

Along the banks of the Mutha river, one can see an old, almost fort-like stone structure on the riverbank. It is flanked by four bastions, a nagarkhana (a drum chamber), two circular rooms, and a flight of wide steps leading down toward the river. "Ghorpade Ghat is said to have been built by Daultrao Ghorpade, a descendant of Peshwa Sardar Yashwantrao Ghorpade, in 1831 CE. Situated on the north bank of the Mutha River and immediately east of Chhatrapati Shivaji Maharaj Bridge, Ghorpade Ghat is a contender for Pune's least cared for heritage structure. There are foundations of two temples at this site. One of them is said to be a Mahadeva temple, while the other one remains unidentified." [3]

"A significant part of Ghorpade Ghat was destroyed by the great flood of 1961, when the earthen-built Panshet Dam situated 50km south-west of Pune broke its banks on the 12th July." [5]

F5:

Present Appearance of Ghorpade Ghat, Pune
Ghorpade Ghat resides on private land, and permission for any works here was refused by the Irrigation Department. No permission has been granted to erect just a simple information board here either. [5]

Neglecting Ghorapde Ghat in Pune River exemplifies a significant urban issue. The lack of maintenance, waste management, and sanitation infrastructure leads to environmental degradation and health hazards. It reflects systemic neglect of urban spaces, highlighting the urgent need for comprehensive urban planning and management to address such pressing issues effectively.

Why have the River ghats lost its relevance?

1. Changing times changed the role and status of the river in the lives of the citizens. Piped water supply at individual homes reduced the daily interaction of the people with the river and its waters.
2. With most of the rivers sources dammed for piped urban supply, the rivers lost their waters and remained mere streams crossing the urban cities.
3. The cultural landscape of this interface, the ghats, was always with a background of temples. Today the role of these temples in the society have been changed directly affecting the usage and significance of the ghats. Cultural festivals and rituals associated with rivers are fast being forgotten.
4. People are not keen on accessing the polluted waters of the river.
5. Ignorance to the importance and value of remains, their occupation by miscredants and beggars, and Absence of illumination post sunset deter people to visit the areas.

Some developments in other cities in India

Sabarmati Riverfront by Dr. Bimal Patel

The project aims to provide Ahmedabad with a meaningful waterfront environment along the banks of the Sabarmati River and to redefine an identity of Ahmedabad around the river. The project has reconnected the city with the river and has positively transformed the neglected aspects of the riverfront. Total area of the development is 506 acres. They have provided various Amenity spaces like Access to Ghats, Exhibition centre, Heritage Plaza, Green pockets, Parks, Sports Complex, Event Ground, Urban forest etc.

The Sabarmati Riverfront Development Project transformed a neglected stretch of the Sabarmati River in Ahmedabad, India, into a vibrant urban space. Completed in 2012, it revitalized the riverbanks with parks, promenades, and cultural amenities, fostering tourism and recreation. The project's success lies in its integration of environmental restoration with urban development, revitalizing the cityscape.

Patna Revitalisation by Ar. Nishant Lall

A large part of city has turned its back to- wards the ganges resulting in misuse of river edge for dumping and waste accumulation. The traditional ghats along the river are also dilapidated and so are a large part of govt land. the scheme plans to integrate this unused land by connecting all the 27 ghats along the 7km stretch and provide a network of urban parks and walkways to improve access to the ghats.

The design components would maximize and optimize the space usage available on the river edge. The proposed promenade has been designed to retrofit the existing boundary conditions with ghats and connecting landscape creating access to river wherever possible. The Patna Riverfront Development Project rejuvenated the banks of the Ganges River in Patna, Bihar. Launched in 2016, it aimed to enhance the city's landscape with parks, walkways, and recreational spaces. By leveraging the river's potential, the project revitalized tourism, improved flood management, and provided a new urban focal point for residents.

Godavari Riverfront Development

Godavari is the second longest river in India after the river Ganges. It is popularly known as “Dakshin Ganga”. The primary objective of the riverfront development was to connect the city to the river, make it more accessible and usable by the residents.

The master plan divided the 5 kms on north and south bank into five zones each. These zones identified the assets and constraints for each zone to generate a proposed set of components, which were unique and yet tied in the complete waterfront together. The first component to achieve a unified waterfront was the riverfront road for the complete 5 km stretch, along with parking and public amenities. The Master Plan focuses on regeneration of the river. The North Bank will be integrated with the existing urban fabric while the less developed South Bank is proposed as an eco-park. [12]

Revitalization of Dravayawati River, Jaipur

Dravyavati River, which is also known as "Amaanishaah naala", has lost its flow and purity of water in past couple of decades. Rapid urbanization in the last 3 - 4 decades coupled with rampant encroachments in the river area and its catchment areas along with the dumping of, industrial waste water and solid waste into dravyavati converted this once pristine flowing river to a Nallah. This project aims to reduce pollution, treat 170 million litres of sewerage a day, create Green Spaces, Social Spaces, Cycle tracks, Jogging tracks along its banks, reduce the threat of floods, create employment, and transform Jaipur into a clean Smart City. [11

Rejuvenating the River Ghats

It is important that all stakeholders are brought to the rivers and river ghats regularly by completely transforming the areas which shall welcome people for various recreational activities. It is important that people use the facilities and benefit out of the same to be able to revisit the areas again and again initiating and integrating change would be the first step towards this Land-water connection.

It is very important and very vital to change the “River in the backyard’ perspective to the ‘Waters in the front court' attitude” to change the status and significance of rivers in the urban cities. This can be achieved by

1. Encouraging the visual - physical- cultural linkage of the city areas with the river spans.
2. Thoughtfully developing the river edges with environmental and ecological sensitiveness.
3. Revive the cultural - religious and social ethos of the river and the river edges.
4. Establish facilities and infrastructure to treat the water and ensure no pollution levels of the flowing waters.
5. Design amenities and facilities for all ages to encourage vibrant interaction.

The planning intervention and the architectural inserts should not just ‘beautify’ the river banks but create and sensitise the people to the age-old relationship towards the flowing waters and the rivers. The planning and Design insert should create a sense of bonding with the sensitive river bank. It is important that awareness about the significance of the natural resource is created as an asset to the city by making the people repeatedly frequent the area to feel, to experience and to interact in the valuable natural spaces rich with environmental benefits, and adhering to vernacular designs.

Revitalising ghats presents an opportunity for urban renewal. Through collaborative efforts, they can be restored with sturdy infrastructure, waste management systems, and green spaces.

Ghats are a series of steps that go to the water and are constructed parallel to the river's flow. They are built to direct water flow, preserve soil, define and stabilise riverbanks, allow access to rivers, and shield communities from flooding. Constructed within the riverine environment, the Ghats enhance the everlasting bond among environment, culture, humanity, and water.

F6: Chandi Ghat of the Patna Riverfront Development, Patna

Along the river ghat one can create Public Amenity and Recreational spaces for e.g. landscaped areas that reinforce the bond between nature, culture, and people also contributing in unifying force, washing away societal divisions and strengthening a sense of shared humanity.

F7: Interaction Space : Ghat of the Patna Riverfront Development, Patna

Riverfront developments can be climate passive by incorporating green infrastructure like vegetated buffers, wetlands, and permeable surfaces, mitigating flooding and reducing heat island effects. Passive design principles such as orientation, natural ventilation, and shading can optimize energy efficiency, minimizing carbon footprint and enhancing resilience to climate change impacts, prioritize water care by implementing sustainable practices such as stormwater management systems, wetland restoration, and erosion control measures.

F8: Chicago Riverfront

Based on factors such as climate and geography, local resource scarcity, and personal histories, riverscapes became a distinctive form of urban architecture for every community. They have developed into locations of human community along the water's edge in response to social, religious, and spiritual requirements also it provides provision for community interaction for different user group.

F9: Yoga practice in the morning

F10: \Chhat Pooja at Benaras

By embracing bioengineering techniques, erosion control measures, wastewater treatment systems, and habitat restoration initiatives, among others, stakeholders can not only safeguard the ecological integrity of ghats but also promote cultural heritage preservation and community resilience. Engaging local communities in the rejuvenation process ensures their

active participation and ownership, leading to more sustainable outcomes in the long run.

Furthermore, through collaborative efforts between policymakers, researchers, communities, and practitioners, it is possible to create a harmonious balance between human activities and natural ecosystems, thereby nurturing a sense of cultural identity and belonging rooted in the landscapes of our rivers.

Conclusion

In conclusion, many of our Urban cities have rivers and Built River ghats, but the river ghats are presently rendered redundant. Revival and rejuvenation of ghats in urban areas through sustainable approaches and biophilia offers a promising avenue for bridging the gap between communities and nature, while fostering a deeper cultural connect. This study highlights the diverse array of spatial options, materials and methods available for revitalising these vital riverbank ecosystems in a manner that is environmentally sound, socially inclusive, and culturally enriching.

In essence, rejuvenating the River ghats in Urban areas and cities through a sustainable approach not only revitalises these important cultural landmarks but also reaffirms our interconnectedness with nature, paving the way for a more resilient and culturally vibrant future for generations to come.

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Sustainable Development Approach For Aquifer Recharge Area

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Abstract:
Chennai city's urban development and encroachments upon the sensitive Aquifer Recharge Area have increased the strain on water resources. Aquifer Recharge Areas in Chennai comprise of notified areas in eight villages. These zones along the East Coast Road are crucial for preventing sea water intrusion, mitigating floods and enhancing climate resilience. It needs to be noted that these areas were severely inundated during the recent Michaung cyclone, 2023. There is a need for sustainable practices to promote environmentally responsible land use, water conservation and resilient urban development. The methodology aims to create a framework to encourage responsible developments, explore strategies like incentives for compliance, punitive action for violation, highlight benefits of good practices and improved public participation. Survey findings from residents across these developments indicate that there is a need to enhance awareness levels about the vulnerability and importance of these zones, increase and motivate compliance to regulations. The existing FSI regulations, with a limit of 0.8 for most areas and 1.0 for declared EWS areas/plots, are sound. However, there are concerns about developments surpassing the allowed limit, and challenges persist in effectively enforcing these regulations. The ongoing development of these areas, if continued, will eventually lead to an ecological imbalance. Hence a comprehensive approach is essential, not only to address the needs, challenges, but also to highlight potential benefits for the stakeholders—development authority, green rating agencies, individual building owners, environmentalists, governmental and private developers. The approach includes real estate strategies assessing the existing developments, along with deriving a sustainability score. The goal is to offer a suitable framework for the city to become resilient; recommend best practices for implementation of regulations which would be both commercially viable and environmentally sustainable.

Keywords:
Aquifer Recharge Area, Resilient Real Estate, Sustainability Score, Frame Work

1. Introduction and Background

Aquifer Recharge Areas are regions designated for the purpose of facilitating the natural replenishment of groundwater through the infiltration of precipitation. The Aquifer Recharge Area in Chennai is delineated by the eastern coastline of the Bay of Bengal, the western boundary marked by the Buckingham Canal, the northern extent reaching the city limits (Thiruvanmiur), and the southern boundary extending to the Chennai Metropolitan Area (CMA) limits (Uthandi). In the second master plan for the Chennai Metropolitan Area (CMA), specific measures have been outlined to safeguard aquifers. The following villages within the delineated area, have been officially identified and declared as Aquifer Recharge Areas. The designation of these areas comes with specific restrictions on development activities to safeguard and optimize the groundwater recharge process. The Villages are as follows:

- Kottivakkam
- Palavakkam
- Neelankarai
- Thuraipakkam
- Injambakkam
- Sholinganallur
- Karapakkam
- Uthandi

However based on recent investigations, it is indicated that there is a presence of seawater intrusion in these villages, as inferred from the measurements of groundwater electrical conductivity. The over pumping of groundwater near the coast may be leading to increase in salination of groundwater. In some regions the electrical conductivity of
groundwater is equivalent to seawater indicates the dominance of seawater in groundwater.

Groundwater depletion threatens the livelihoods of the people as well as the ecosystem. Diverse economic activity, overpopulation, and climate change in the coastal regions have put freshwater resources at high risk [2]. Proper and efficient management of coastal groundwater resources is very essential and is an integral part of coastal zone management [1].

Despite the existing conditions, during the 270th Authority Meeting held on July 11, 2022 by Chennai Metropolitan Development Authority, discussions have ensued regarding representations favoring an increase of the Floor Space Index (FSI) for the Aquifer Recharge Areas. Following thorough deliberation, the Authority has resolved to task a committee, formed to conduct a comprehensive scientific analysis of developments in the Aquifer Recharge Area within the Chennai Metropolitan Area, and submitting its report for the Authority's consideration and subsequent decision-

making [4].

In August 2023, an interim report was delivered by the Centre for Urbanisation, Buildings & Environment (CUBE) to the Chennai Metropolitan Development Authority (CMDA). It stated that there is no requirement to modify development regulations until 2033. Also, according to the report, the current population in the aquifer recharge area stands at 4.9 lakh, and that this accounts for 61.9% of its maximum holding capacity, which is 8 lakhs, indicating that there is considerable space for population growth and development while maintaining adherence to existing regulations [22].

However, the same report also claims that the current water supply is 8.8 MLD for 2023, whereas the demand as per the current population is 55 MLD. And with maximum densification, the requirement would be 77 MLD. The report also specifies that only 15% of the current population can be catered to with a metro-water supply and the rest of the population will be dependent on other sources, including groundwater [22].

This seems contradictory as increase in population up to maximum holding capacity of 8 lakhs will lead to increased stress on ground water sources. This will further impact the Aquifer Recharge Area. Therefore, there arises a need to understand the water consumption rates with respect to natural ground water replenishment rates through precipitation.

The report also highlights a decline in the 'No Development Zone' from 1,739 acres in 2011 to 1,495 acres in 2019, indicating reduced open and agricultural land alongside increased built-up areas. Therefore, it is essential to assess the current rules and regulations, analyze the level of development in these zones, ascertain the existing status of development, and underscore the implications of higher FSI [22].

2. Aim

- To understand the existing conditions of the aquifer recharge zones.
- Identify challenges and opportunities.
- Promote sustainable development, preserve these sensitive zones

3. Objectives

- Quantify the Aquifer Recharge Area within the Chennai Metropolitan Area, examine the existing population and households, and understanding the subsurface composition.
- Understand the existing rules and regulations governing developments in Aquifer Recharge Area.
- Evaluate developments across asset classes by comparing the current Floor Space Index (FSI) with a hypothetical 2.0 FSI, considering potential regulatory adjustments as being discussed by Chennai Metropolitan Development Authority [21].
- Quantify existing developments in Aquifer Recharge Area.
- Evaluate current developments across different asset classes in Aquifer Recharge Area.
- Assess the level of awareness among stakeholders regarding Aquifer Recharge Area.
- Develop a sustainable development framework guided by the findings.
-

4. Methodology

- Overlay Map MP-II/CMDA No. 10 / 2008, CMA Aquifer Recharge Area Map [5] in QGIS, determine overall extent of Aquifer Recharge Area and Village wise Area under Aquifer Recharge Area.
- Gather population and household data from the Census of India [13] for the study area, and understand average household size.
- Overlay District Resource Map from Geological Survey of India [6] and extract information on the subsurface compositions pertaining to study area.
- Understanding the existing Regulations and Guidelines governing developments in Aquifer Recharge Area from Appendix A of Tamil Nadu Government Gazette Extraordinary [14].
- Comparative Analysis between developments asset class wise. One with existing FSI and the other a hypothetical FSI of 2.0. Understanding the water requirements for both the scenarios with water replenishment rates. As balancing water extraction rates with natural recharge rates is crucial for sustainable aquifer management.
- Leverage Arch GIS World Imagery within QGIS as the primary geospatial framework to extract data pertaining to existing built structures and the road network. Calculate both the overall development percentage and the normalized development percentage to understand the extent of development in each village.
- Assess current developments across different asset classes by utilizing evaluation criteria vital for the preservation of Aquifer Recharge Areas. This includes benchmarking water consumption against natural replenishment rates and verifying adherence to existing rules and regulations governing developments to safeguard these environmentally sensitive areas.
- Conduct a survey among residents in the study area to assess their awareness levels and understanding of the significance of Aquifer Recharge Areas.
- Develop a suitable framework for sustainable development, integrating findings with literature review and best practices.

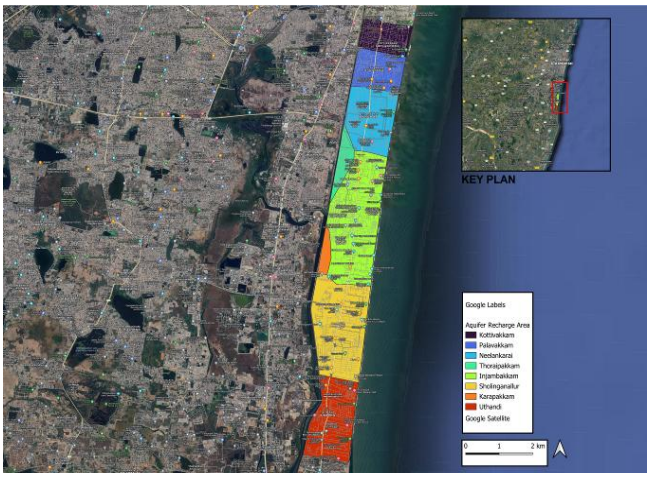
5. Quantifying Aquifer Recharge Areas

Village *)*	***Tot***	***Area Unde*** *(In Acres)*	***Percentage share of Area under Aquifer Recharge Zone***
Kottivakkam	608	327	54%
Palavakkam	682	397	58%
Neelankarai	670	637	95%
Thoraipakkam	1460	161	11%
Injambakkam	1277	1267	99%
Sholinganallur	3922	1066	27%
Karapakkam	604	86	14%
Uthandi	842	716	85%

Table 1(a): Village-wise Distribution of Total Area and area under Aquifer Recharge Zone

After superimposing the CMA-Aquifer Recharge Area map onto the Survey of India's Topographic Map (D44U5_66D5 series) and subsequently conducting geo-referencing in QGIS using WGS 84 coordinates (Authority ID: EPSG 4326) as the designated coordinate system for the project, the total area of the study region was determined to be 4657 acres. The study area was subdivided based on the village boundaries outlined in the CMA maps. Subsequently, the areas of each specific villages falling within the Aquifer Recharge Area were computed as represented in Table 1.(a).

Population and household data for the villages within



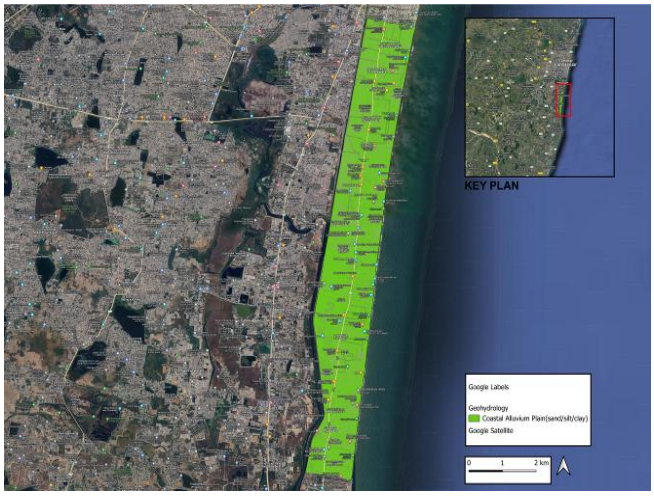
F1:

the study area was extracted from the District Census Handbook for the years 2001 and 2011[13]. It's important to note that only specific portions of each village fall within the Aquifer Recharge Area within the overall village extent. The percentage share of the area falling under the Aquifer Recharge Area was calculated. This calculation was then employed to determine the percentage share of both population and the number of households associated with this specific area

6. Subsurface Compositions

The study area is a young coastal plain, this indicates a recently formed geological feature adjacent to the coast, likely characterized by flat or gently sloping terrain sculpted by coastal processes such as sediment deposition and erosion.

The lithology is characterized by sedimentary deposits, which likely dominate the composition. The permeability is cumulatively high, facilitating the movement of fluids and supporting significant groundwater flow and recharge characteristics indicate the presence of deep sandy soils with somewhat excessive drainage, indicating rapid water drainage through the soil profile. The composition comprising sand, silt, and clay signifies a blend of sedimentary deposits. This alluvial accumulation serves a crucial function in replenishing groundwater, influencing aquifer characteristics, and impacting the dynamics of coastal ecosystems [6].



F2: Soil. Base map: Google Earth

***ge** (falling under Aquifer Recharge Area)*	**2001 :Population Share** (Considering Percentage Share Under Aquifer Recharge Zone)	**2001 :Household Share** (Considering Percentage Share Under Aquifer Recharge Zone)	***2001:Aaged Size***	**2011 :Population Share** (Considering Percentage Share Under Aquifer Recharge Zone)	**2011 :Household Share** (Considering Percentage Share Under Aquifer Recharge Zone)	***e***
Kottivakkam	7485	1753	4.3	10875	2814	3.9
Palavakkam	8364	1937	4.3	15581	3962	3.9
Neelankarai	14923	3428	4.4	27070	7043	3.8
Thoraipakkam	2861	687	4.2	8445	2220	3.8
Injambakkam	10178	2430	4.2	21355	5405	4.0
Sholinganallur	7457	1721	4.3	17065	4403	3.9
Karapakkam	540	133	4.1	1275	348	3.7
Uthandi	2123	486	4.4	4282	1118	3.8

Table 1(b): Village-wise Distribution of Population and Household Share: 2001 and 2011

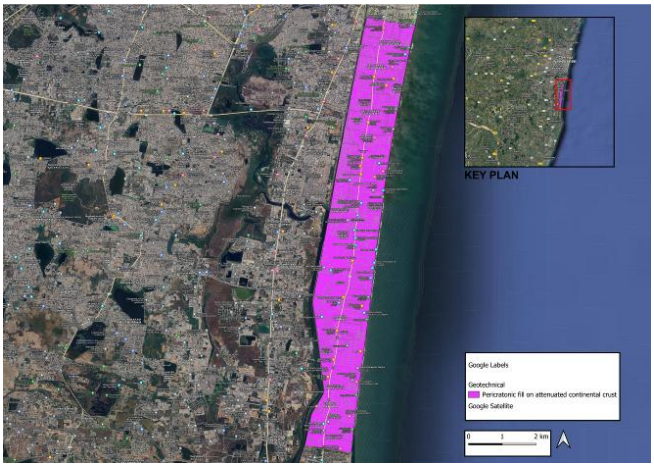
7. Policy Snapshot: Existing Regulations and Guidelines (as per Tamil Nadu Combined Development and Building Rules, 2019) [14].

Permissible Developments

7.1 Residential

- Residential Buildings
- Working Women's Hostel / Old Age Homes
- Hostels and Dormitories
- Swimming Pool attached to residential activity in a plot

7.2 Commercial



- Professional Consulting Offices
- Petty Shops.
- Assembly Halls, Welfare Institutions
- Daily or Weekly Markets
- Restaurants
- Departmental Stores
- Fuel Filling Stations
- Cinema Theatres
- Large Developments on Plots Not Less Than 1 Hectare: Beach cottages, hotels, tourism-based developments.

7.3 Public/ Semi Public

- Schools of Commerce
- Educational Institutions
- Government/Semi-Government Offices
- Transport Depots
- Public Utility Buildings
- Health Facilities
- Burial Grounds
- Religious Buildings
- Large Developments on Plots Not Less Than 1 Hectare: Educational, technical, and research institutions.

7.4 Industrial

- Cottage Industries
- Storage of Domestic Cooking Gas Cylinders
- Service Industries

7.5 Recreational

- Parks,
- Playgrounds,
- Farms
- Large Developments on Plots Not Less Than 1 Hectare: Recreational activities

7.6 Development Regulations: Site Extent, Plot Coverage, FSI, and Setback Guidelines

Descri	***Natham/declared EWS areas / EWS plots***	***Other Areas***
Minimum plot extent	80 sq.m	220 sq.m.
Minimum frontage	4.5m	12m
Maximum FSI	1.00	0.80
Maximum Plot coverage	50%	40%
Maximum height	9.0m (G+1 or stilt +2 floors)	9.0m (G+1 or stilt +2 floors)

Table 2: Existing Regulations (as per TNCDBR, 2019) [14].

Descri	***Natham/declared EWS areas / EWS plots***	***Other Areas***	
Minimum set back 14643			
Minimum Front Set Back	1.5m	***Abutting Road Width***	***Minimum Front Setback***
		Upto 9m	1.5m
		Above 9m but less than 18m	3.0m
		Above 18m but less than 30.5m	4.5m
		Above 30.5 m	6.0m
Minimum Side Setback	Nil	2m on either side	
Minimum Rear Setback	Nil	2m activity in a plot	

7.7 Special Cases of Permissible Developments (as per Tamil Nadu Combined Development and Building Rules, 2019)[14].

- Assembly halls and welfare institutions with a floor area not exceeding 300 sq.m. and a maximum height of 18.30m (up to the crown level in the case of sloped roofs).
- Public Utility Buildings such as sewage-pumping stations, water works, fire stations, and telephone exchanges, with a maximum height not exceeding 18.30m.
- Air-conditioned cinema theaters and open-air theaters with a maximum height not exceeding 18.30m, located adjacent to a minimum 12m wide road.
- On plots/sites not less than 1 Hectare. in extent:

Beach cottages, hotels and tourism-based developments as may be decided by the Authority not exceeding 18.30m in height.
Recreational activities not exceeding 18.30m. in height Educational, technical and research institutions not exceeding 18.30m in height.

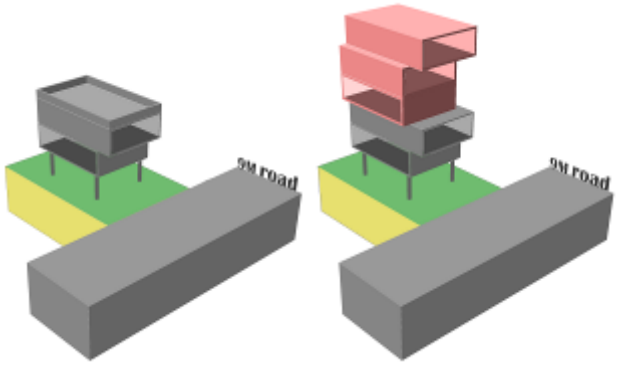
8. FSI Assessment: Contrasting Asset Class-Wise Existing 0.8 FSI with a Hypothetical 2.0 FSI

The Interim Report by CUBE suggests that there is no need to change the existing regulations until 2033. Meanwhile it is important to understand the implications of increased FSI, and how it will impact the sustainability of the Aquifer Recharge Areas.

This study aims to compare developments under both existing regulations and a potential increase in FSI. The minimum requirement for the calculation and assumed values have been derived from academic research work specific to the typology or asset class, alongside a benchmarking system, rather than being guided by the Statutory Guidelines/Framework stipulated by regulatory authorities.

8.1 Residential

A residential site spanning 220 sq.m with a 9m access road is examined. Taking into account a plot coverage of 40% for both scenarios namely development with an FSI of 0.8(existing) and hypothetical FSI of 2.0.



Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	220 sq.m.	220 sq.m.
Permissible Built-up Area	176 sq.m.	440 sq.m.
Plot coverage	40%	40%
Floor Area	88 sq.m	88 sq.m
No of Floors	Stilt+2	Stilt+5

In the first scenario, for residential development with a 0.8 FSI, it is considered that two families reside in this development, with each occupying one floor.

Considering the average household size as 3.85 (average household size across the eight villages as per Census Tables for the year 2011 by Office of the Registrar General & Census Commissioner, India from Table 1*(c)*)[13], we can say that a total of 7.7 residents occupy this residential development. The overall annual water requirement would be 379,417 litres/year (considering 135litres/head/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3].

On the other hand, for the development with an FSI of 2.0, it is considered that five families reside in this residential development, each occupying one of the five floors individually. Taking the same average household size, we can say that a total of 19.25 residents occupy this residential development. The overall annual water requirement would be 948,543.75 litres/year.

Considering an average rainfall of 1447mm for Chennai (as per Rainfall Statistics of India – 2022 by India Meteorological Department (Ministry of Earth Sciences)) [11] and a run off coefficient of 2, the overall volume of rainwater which could possibly be tapped would be 318,340 litres/year. It is to be noted that developments with an FSI of 2.0 have water requirement which is almost 2.97 times higher than the potential volume of rain water which could be tapped. It is also important to note even with the existing regulation of 0.8 FSI the water requirement is slightly higher at 1.19 times the potential recharge through precipitation.

8.2 Commercial

Restaurant

As per existing regulations, for a restaurant within the commercial asset class category, the floor area must not exceed 300 sq.m. [14], and its structure should comprise a ground floor (G) and an additional floor (G+1). These guidelines are applicable, provided that the access road has a minimum width of 10 meters. Since the plot coverage is capped at 40%, the extent of site for a permissible floor area of 300 sq.m shall be 750 sq.m. Taking into account a plot coverage of 40% for both scenarios namely development with an FSI of 0.8(existing) and hypothetical FSI of 2.0.

Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	750 sq.m.	750 sq.m.
Permissible Built-up Area	600 sq.m.	1500 sq.m.
Plot coverage	40%	40%
Floor Area	300 sq.m	300 sq.m
No of Floors	G+1	G+4
No of Seats	258	646

Table 3(b): Restaurant:

In the first case the restaurant with 0.8 FSI has a built up area of 600 sq.m. Considering 60% of the total built up area as reserved for Dining, remaining 40% for the Kitchen (as per Restaurant Design and Interior Layout – The Project Guide from CSJMU Kanpur (Formerly Known as Kanpur University) [19], the total dining area would be 360 sq.m. Taking into account 15 sqft (1.39355 sq.m) per head as the space requirement for the restaurant, we get a total of 258 seats (as per IGNOU - The People's University-Setting Up Food Service Unit) [20].

The water requirement would be 65,91,900 liters/year. (considering 70litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS) [3].

On the other hand, for 2.0 FSI, the built-up area would be 1500 sq.m. The total number of seats in this case would be 646 (as per IGNOU - The People's University-Setting Up Food Service Unit) [20]. The water requirement in this case would be 1,65,05,300 liters/year (considering 70litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS) [3].

However, the overall volume of rainwater which could possibly be tapped would be 10,85,250 litres/year. In both the scenarios the water requirement is significantly higher than the potential volume of rain water which could be tapped. For restaurant developments with FSI of 0.8 and 2.0, the water demand would exceed potential recharge through precipitation by 6.07 times and 15.20 times, respectively.

Office

As per existing regulation, for an office within the commercial asset category, the floor area must not exceed 300 sq.m.[14], and its structure should comprise a ground floor (G) and an additional floor (G+1). Since the plot coverage is capped at 40%, the extent of site for a permissible floor area of 300 sq.m shall be 750 sq.m. Taking into account a plot coverage of 40% for both scenarios namely development with an FSI of 0.8(existing) and hypothetical FSI of 2.0.

Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	750 sq.m.	750 sq.m.
Permissible Built-up Area	600 sq.m.	1500 sq.m.
Plot coverage	40%	40%
Floor Area	300 sq.m	300 sq.m
No of Floors	G+1	G+4
No of Seats	81	202

Table 3(c): Office: Comparative Analysis

In the first case the office with 0.8 FSI has a built-up area of 600 sq.m. Now considering 80 sqft (7.43224 sq.m) per head as the space requirement for the office, there would be a total of 81 seats (as per JM Financial, Sector Report Flexible office spaces) [18]. The water requirement would be 13,30,425 liters/year (considering 45litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3].

On the other hand for 2.0 FSI, the built up area would be 1500 sq.m. The total number of seats in this case would be 202. The water requirement in this case would be 33,17,850 liters/year.

However the overall volume of rainwater which could possibly be tapped would be 10,85,250 litres/year. For office buildings with FSI of 0.8 and 2.0, the water demand would be 1.22 and 3.05 times, the potential recharge through precipitation respectively.

Cinema Halls

Assessing a cinema hall within the commercial asset category, a site spanning 10000 sq.m
(1 hectare) has been considered. Taking into account a plot coverage of 40% for both scenarios namely development with an FSI of 0.8(existing) and hypothetical FSI of 2.0.

In the first case for a cinema hall with 0.8 FSI, the built up area would be 8000 sq.m. In order to determine the number of seats for this development, two theaters located within the study area, are considered as benchmarks for comparison. The ratio of seats to built-up area was calculated for both the theaters.

Theater	***Built-up Area***	***No of seats***	***Seats per built-up area***
Case Study 1	6244 sq.m.	1400.	0.22
Case Study 2	4268 sq.m.	625	0.14

Table 3(d): Cinema: Benchmarking

Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	10000 sq.m.	10000 sq.m.
Permissible Built-up Area	8000 sq.m.	20000 sq.m.
Plot coverage	40%	40%
Floor Area	4000 sq.m	4000 sq.m
No of Floors	G+1	G+4
No of Seats	1440	3600

Table 3(d'): Cinema: Comparative Analysis

The average seat-to-built-up area ratio derived from both comparable theaters is 0.18. This gives a total of 1440 seats. The water requirement in this case would be 7,884,000 liters/year (considering 15litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3].

On the other hand for 2.0 FSI, the built up area would be 20000 sq.m. The total number of seats in this case would be 3600. The water requirement would be 19,710,000 liters/year (considering 15litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3].

However the overall volume of rainwater which could possibly be tapped would be 14,470,000 litres/year. For cinema halls with FSI of 0.8 and 2.0, the water demand would be 0.54 and 1.36 times the potential recharge through precipitation respectively.

Hotels-4 Star

Considering a site spanning 10,000 square meters, a 4-star hotel within the commercial asset category has been assessed. Taking into account that hotels rated 4 stars and above have a higher water requirement in comparison to 3 star hotel (i.e 320 litres/head/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3]. Additionally, a plot coverage of 40% has been considered for both scenarios.(as per existing regulations)[14].

Description	*Existing 0.8 FSI*	*Hypothetical 2.0 FSI*
Plot Area	10000 sq.m.	10000 sq.m.
Permissible Built-up Area	8000 sq.m.	20000 sq.m.
Plot coverage	40%	40%
Floor Area	4000 sq.m	4000 sq.m
No of Floors	G+1	G+4
No of Keys	66	166

Table 3(e): Hotel 4 Star:: Comparative Analysis

In the first case the 4 Star Hotel with 0.8 FSI has a built up area of 8000 sq.m. Considering 120.37 sq.m per key as the Gross Floor Area/key (as per 2023 Hotel Development Cost Survey by Hotelivate)[16], there will be 66 keys. Taking into account 2 people per key and an annual occupancy rate for Hotels in Chennai as 68.7% (as per 2023 Indian Hospitality trends and Opportunities by by Hotelivate)[17]. The water requirement would be 10,591,891.2 liters/year.

On the other hand, for 2.0 FSI, the built-up area would be 20000 sq.m. The total number of keys in this case would be 166. The water requirement in this case would be 26,640,211.2 liters/year.

However, the overall volume of rainwater which could possibly be tapped would be 14,470,000 litres/year. For 4-star hotels with FSI of 0.8 and 2.0, the water demand would be 0.73 and 1.84 times the potential recharge through precipitation respectively.

8.3 Public/ Semi Public - Schools without boarding facilities

Assessing a school within the public/semipublic asset Category, a site spanning 10000 sq.m has been considered (1 hectare). Additionally, a plot coverage of 40% has been considered for both scenarios. In order to determine the number of students per square meter of built-up area, nine schools located within the study area, have been considered as benchmarks for comparison. The ratio of no of students to built-up area was calculated for all the comparable.

School	*Built-up Area*	*No of students*	*Students per built-up area*
Case Study 1	3330	800	0.240
Case Study 2	3681	466	0.127
Case Study 3	4703	290	0.062
Case Study 4	3292	821	0.249
Case Study 5	1230	255	0.207
Case Study 6	2449	308	0.126
Case Study 7	4747	890	0.187
Case Study 8	3252	1450	0.446
Case Study 9	3885	800	0.206

Table 3(f): Schools: Benchmarking, Students per Built-up area

The average no of students-to-built-up area ratio derived from comparable schools is 0.199.

In the first case the school with 0.8 FSI has a built-up area of 8000 sq.m. The number of students would be 1592. This gives a total of 40 sections (as per Clause 4.8: Enrollment And Section Restriction In Each Class – CBSE School Infrastructure) [8]. The total of teaching staff would be 113 (as per Mandatory Directions of The Board with Regard to Teacher Qualification & Number of Teachers – CBSE Schools) [9]. The total number of non-teaching staff would be 10 (as per Report on Unified District Information System Plus (UDISE+) 2021-22 Flash Statistics) [10]. Therefore, the total number of users would be 1715. The total number of working days is 220 (As per section 19 of the RTE ACT-2009 and National Curriculum Framework for School Education 2023) [12], the total water requirement would be 16,978,500 liters/year (considering 45litres/seat/day as per Estimation of water requirement for drinking and domestic use by Central Ground Water Authority, Government of India (Source: NBC 2016, BIS))[3].

On the other hand, the school with 2.0 FSI has a built-up area of 20000 sq.m. The number of students would be 3980. This gives a total of 100 sections (as per Clause 4.8: Enrollment and Section Restriction in Each Class – CBSE School Infrastructure) [8]. The total of teaching staff would be 283 (as per Mandatory Directions of The Board with Regard To Teacher Qualification & Number Of Teachers – CBSE Schools) [9]. The total number of non-teaching staff would be 25 (as per Report on Unified District Information System for Education Plus (UDISE+) 2021-22 Flash Statistics) [10].

Therefore, the total number of users would be 4288. The total number of working days is 220 (As per section 19 of the RTE ACT-2009 and National Curriculum Framework for School Education 2023) [12], the total water requirement would be 42,451,200 liters/year.

Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	10000 sq.m.	10000 sq.m.
Permissible Built-up Area	8000 sq.m.	20000 sq.m.
Plot coverage	40%	40%
Floor Area	4000 sq.m	4000 sq.m
No of Floors	G+1	G+4
No of Students	1592	3980
No of teaching staff	113	283
No of non-teaching staff	10	25
Total no of users	1715	4288

Table 3(f'): Schools without boarding facilities: Comparative Analysis

However, the overall volume of rainwater which could possibly be tapped would be 14,470,000 liters/year. For schools with FSI of 0.8 and 2.0, the water demand would be 1.17 and 2.93 times the potential recharge through precipitation respectively.

Technical Institutions without boarding facilities

Assessing a Technical Institution within the public/semi- public asset category, a site spanning 10000 sq.m (1 hectare) is taken into account. A plot coverage of 40% for both scenarios has been considered (as per existing regulations).

In the first case, for a technical institution with 0.8 FSI the built-up area would be 8000 sq.m. The number of students would be 672, the number of teaching staff would be 68 (as per Annexure: I Norms and Requirements AICTE) [7] and a total of 56 non-teaching staff (as per Annual Status of Higher Education (ASHE), 2023 In states and union territories in India) [15]. Therefore, the total number of users would be 796. Considering the total no of working days as 240 (as per TNMGRMU, Regulations of attendance for Under Graduate and Post Graduate Degree Courses) [23], the total water requirement would be 85,96,800 litres/year.

On the other hand, for 2.0 FSI, the built-up area would be 20000 sq.m. The total number of users would be 1987. The water requirement in this case would be 21,459,600 liters/year. However, the overall volume of rainwater which could possibly be tapped would be 14,470,000 litres/year. For Technical Institutions with FSI of 0.8 and 2.0, the water demand would be 0.59 and 1.48 times the potential recharge through precipitation respectively.

Description	***Existing 0.8 FSI***	***Hypothetical 2.0 FSI***
Plot Area	10000 sq.m.	10000 sq.m.
Permissible Built-up Area	8000 sq.m.	20000 sq.m.
Plot coverage	40%	40%
Floor Area	4000 sq.m	4000 sq.m
No of Floors	G+1	G+4
No of Students	672	1680
No of teaching staff	68	169
No of non-teaching staff	56	138
Total no of users	796	1987

Table 3(g): Technical institutions without boarding facilities: Comparative Analysis

The Fig.3(b) presents a concise overview comparing water demands across different asset classes, expressed as multiples of the annual rainfall available (no of times).

Two scenarios are depicted: one with a floor space index (FSI) of 0.8 for developments (shown in blue), and the other with an FSI of 2.0 (depicted in red).

This comparison of water requirements based on different FSIs across the asset classes helps to assess the impact of urban development density on water consumption in relation to available rainfall.

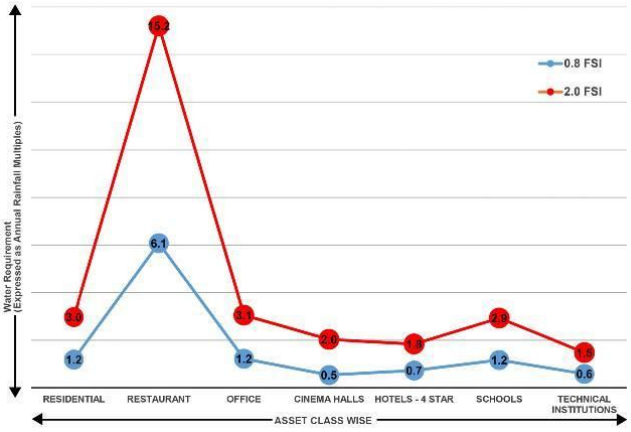


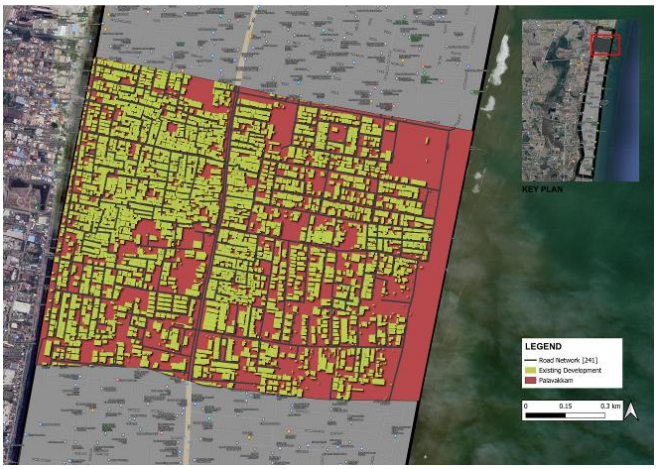
Table 4(a): Village wise: Extent of existing development and road networks

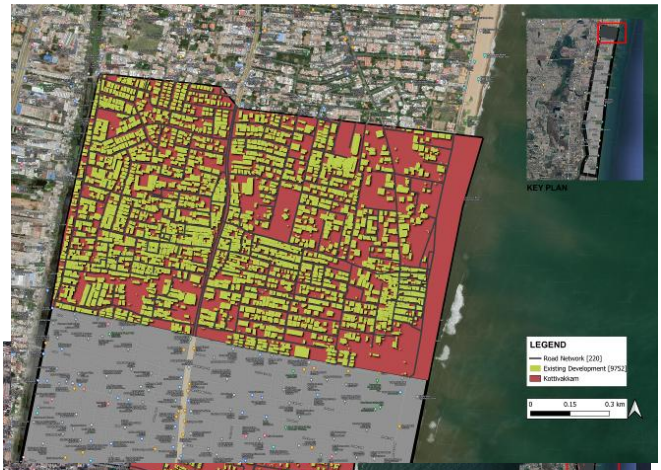
9. Quantifying Existing Developments-Aquifer Recharge Areas

The current state of the built environment and the road network has been assessed by leveraging Arch GIS World Imagery as the primary geospatial foundation. This involved extracting existing built structures and the road network.

Following that, the built structures and road network were split on a village-by-village basis. This segmentation process was carried out by utilizing the exact village boundaries outlined in the Chennai Metropolitan Area (CMA) maps.

10. Evaluating Current Developments Across Asset Classes





10.1 Evaluation Criteria

Aquifer recharge areas are renowned for naturally replenishing groundwater through precipitation infiltration, thus balancing water extraction rates with natural recharge rates is crucial for sustainable aquifer management. Existing policy frameworks are in place to regulate developments and ensure the long-term sustainability of these zones. Key parameters governing developments in these zones include FSI, plot coverage and permissible height. These parameters along with the water replenishment capacity, are collectively utilized as the primary evaluation criteria referred to as the Sustainability Score in this context. Each parameter

is individually assessed, and their averages are considered for evaluation.

10.2 Floor Space Index (FSI)

The permissible Floor Space Index (FSI) for developments in Aquifer Recharge Areas is 0.8(as per TNCBDR, 2019) [14]. Employing this as the benchmark, scores for each development is calculated. For instance, if a development achieves an FSI of 0.8, it earns a score of 100, and scores decrease for those exceeding the approved limit.

The calculated score is termed the 'FSI Score' and is determined by applying the specified formula.

$$FSI\ Score = 100 \times \left[1 - \frac{\text{MAX}(0,\ x - 0.8)}{0.8}\right]$$

(here x is the FSI achieved by the particular development)

10.3 Height

The approved height for developments in these regions is 9m, except for special cases outlined in the Policy Snapshot: Existing Regulations and Guidelines.(as per TNCBDR, 2019)[14].

A score of 100 is assigned to developments adhering to height restrictions. For developments exceeding the permissible limit with additional floors, points are deducted for each non-permissible floor as per percentage of non-permissible floors. The calculated score is termed the 'Height Score' and determined by applying the specified formula.

$$\text{Height Score} = 100 - \left[(\text{y-no of permissible floors}) \times \frac{(\text{y-no of permissible floors})}{\text{no of permissible floors}} \times 100\right]$$

(here y is the total number of floors in the particular development)

10.4 Plot Coverage

The permissible Plot Coverage for developments is 40% (as per TNCBDR, 2019)[14]. Employing this as the benchmark, scores for each development is calculated. For example, if a development attains a plot coverage of 40%, it receives a score of 100, and scores decrease for those surpassing the approved limit. The calculated score is termed the 'Plot Coverage Score' and determined by applying the specified formula.

$$\text{Plot Coverage Score} = 100 \times \left[1 - \frac{\text{MAX}(0,\ z - 40\%)}{40\%}\right]$$

(here z is the plot coverage achieved by the particular development)

10.5 Water Consumption

Given an annual rainfall of 1447mm (as per Rainfall Statistics of India – 2022 by India Meteorological Department (Ministry of Earth Sciences)) [11] and a runoff coefficient of 1, the available rainfall volume per sqft equates to 134.42 liters. The water consumption of the developments has been assessed. Developments with water requirements aligning with the available rainfall per square foot receive a perfect score of 100. As water consumption increases, the score diminishes. The calculated score is termed the 'Water Score' and determined by applying the specified formula.

$$\text{Water Score} = 100 \times \left[1 - \frac{\max(0,\ w - 134.42)}{134.42}\right]$$

(here w is the water requirement per sqft for the particular development)

10.6 Sample Size and Means of data collection

Residential

A total of 36 residential samples from the study area were collected. These samples were sourced through surveys as well as listings provided by developers. Detailed documentation was carried out for each sample, capturing key attributes such as overall property extent, plot coverage, number of floors, and built-up area. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage, and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

Schools

A total of 9 samples were collected. These samples were sourced from documents available through the 'Mandatory public disclosure' documents. Apart from capturing essential attributes like overall property extent, plot coverage, number of floors, and built-up area, data regarding the total number of students, teaching and non-teaching staff were also documented. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage, and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

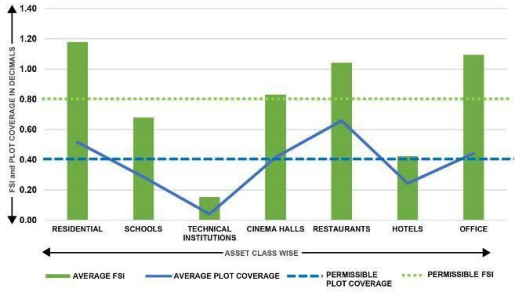
Technical Institutes

The samples include the only two technical institutes in the study area. Detailed documentation was carried out for each sample, capturing key attributes such as overall property extent, plot coverage, number of floors, and built-up area. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage, and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

Cinema Halls

Similar to the Technical Institutes the samples include the only two cinema halls in the study area. Detailed documentation was carried out for each sample, capturing key attributes such as overall property

extent, plot coverage, number of floors, and built-up area. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage, and water requirement. Subsequently, scores were assigned to each sample based on predefined



evaluation criteria outlined in the research paper.

Restaurants
A total of 5 samples were collected. These samples were sourced through online listings and through survey. Apart from capturing essential attributes like overall property extent, plot coverage, number of floors, and built-up area, the total no of seats were also documented. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

Hotels
A total of 5 samples were collected. These samples were sourced through online listings and through survey. Apart from capturing essential attributes like overall property extent, plot coverage, number of floors, and built-up area, the total no of keys were also documented. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

Office
A total of 5 samples were collected. These samples were sourced through online listings and through survey. Apart from capturing essential attributes like overall property extent, plot coverage, number of floors, and built-up area, the number of workstations were also documented. This data was then utilized to compute important metrics including the Floor Space Index (FSI), plot coverage and water requirement. Subsequently, scores were assigned to each sample based on predefined evaluation criteria outlined in the research paper.

11. Stakeholder Awareness Levels

11.1 Residents

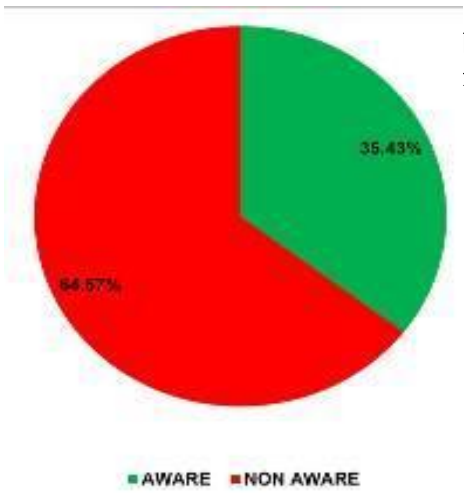
A total of 1067 samples were collected. These samples were gathered through the distribution of surveys, which were made available both online and in person to residents. The questions inquired whether residents were familiar with the concept of 'Aquifer Recharge Area' and whether they were aware that they were currently residing in such notified areas.

The questions were made available in both Tamil and English. The survey findings indicate that approximately 64.5% were unaware.

Another important finding is that all the respondents claimed to be using bore wells as the primary source of water for all household purposes.

Figure 6(a): Awareness levels among residents

Inferences based on findings



12.1 Residential

- The Sustainability Score for this asset class, as determined by the collected samples, is 68, suggesting a low level of stakeholder compliance and higher water consumption rates in comparison to replenishment rates.
- Samples collected show that existing residential developments surpass permissible FSI limits by nearly 50%, with an average FSI of 1.18.
- Likewise, plot coverage exceeds permissible limits by 30%, this reduces the surface area for direct infiltration of precipitation into the Aquifer. Thereby reducing recharge.
- The implementation of an FSI of 2.0 in the future would lead to heightened strain on current groundwater resources, and eventually result in severe water scarcity crises and long-term environmental damage.
- There exists a low level of awareness among residents regarding the Aquifer Recharge Area.

12.2 Schools

- The Sustainability Score for this asset class, as determined by the collected samples, is 90, suggesting a higher level of stakeholder compliance and lower water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 0.68, which is lower than the permissible limit of 0.8.
- Likewise, the average plot coverage is at 29%, which is lower than the permissible limit of 40%

12.3 Technical Institutions

- The Sustainability Score for this asset class, as determined by the collected samples is 100, suggesting highest level of stakeholder compliance and lower water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 0.15, which is much lower than the permissible limit of 0.8.
- Likewise, the average plot coverage is at 4%, which is also much lower than the permissible limit of 40%

12.4 Cinema Halls

- The Sustainability Score for this asset class, as determined by the collected samples is 92, suggesting higher level of stakeholder compliance and lower water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 0.83, which is slightly above the permissible limit of 0.8.
- Likewise, the average plot coverage is at 42%, which is also slightly above the permissible limit of 40%

12.5 Restaurants

- The Sustainability Score for this asset class, as determined by the collected samples is 51, suggesting lowest level of stakeholder compliance and high-water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 1.04, which is slightly above the permissible limit of 0.8.
- Likewise, the average plot coverage is at 66%, which is above the permissible limit of 40%

12.6 Hotels

- The Sustainability Score for this asset class, as determined by the collected samples is 98, suggesting higher level of stakeholder compliance and lower water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 0.42, which is much lower than the permissible limit of 0.8.
- Likewise, the average plot coverage is at 24%, which is also lower than the permissible limit of 40%.

12.7 Office

- The Sustainability Score for this asset class, as determined by the collected samples is 65, suggesting a lower level of stakeholder compliance and water consumption rates in comparison to replenishment rates.
- Samples collected show that existing developments have an average FSI of 1.09, which exceeds the permissible limit of 0.8 by 36%.
- Likewise, the average plot coverage is at 44%, which is higher than the permissible limit of 40%.
-

13. Framework for Sustainable Development

In the face of escalating threats to Chennai's aquifer zones, the current the existing status of developments and encroachment into no development zones pose an imminent risk to the city's water security. The potential shift to a 2.0 FSI could amplify this crisis, demanding urgent and decisive action. As we navigate this critical juncture, the following recommendations and market-based instruments are crucial for steering policy towards sustainable urban development, safeguarding aquifer recharge areas, and ensuring a resilient future for Chennai's water resources.

13.1 *0.8* FSI can be the new *2.0*

For proposed new developments in Aquifer Recharge Areas, Transferable Development Rights (TDR) can be effectively used as compensation by providing landowners with transferable development certificates for the remaining 1.2 FSI for adherence to existing FSI of 0.8. This TDR can be seen as another form of the Premium FSI [14] which is available as per existing development control rules, however it should be mandated such that this TDR from Aquifer Recharge Areas cannot be used above the Premium FSI. Potential Stakeholder can either choose between Premium FSI from the Development Authority or TDR from landowners in Aquifer Recharge Area.

13.2 Property Tax guided by Sustainability Score

It is suggested to make mandatory the disclosure of Sustainability Score for each development, to be verified and challenged by Stakeholders and Development Authority. Offering property tax incentives for developments achieving higher Sustainability Scores, while implementing tax increases with multipliers corresponding to reduced scores could be recommended.

13.3 Incentivizing Water Tax Payments Based on Asset-Class Wise Water Requirements.

It is suggested to revise water tax rates based on the water requirements of each asset class. Applying higher charges to asset classes with greater water demands, while offering incentives to those with water requirements equal to or lower than natural replenishment of ground water through precipitation could also be recommended. The water requirement for different asset classes expressed as multipliers of annual rainfall available is represented in Fig.3(b).

13.4 Permeable Networks and Sustainable Service Systems

The total length of the current road network in the study area measures approximately 381 Kms. In villages such as Injambakkam, Shollinganallur, Karapakkam, and Uthandi within the study area, the normalized development percentage is below 40%, indicating that over 60% of these areas remain undeveloped. As a result, any future developments proposed for these areas must include mandatory construction of permeable roads and pavements to facilitate recharge. This requirement may also be extended to other villages located within the Aquifer Recharge Area.

13.5 Conduct Public Awareness Drives.

Survey results indicate that 64% of residents are not aware of the sensitive nature of the Aquifer Recharge Area. It is important to create awareness and educate the society at large about the implications of disregarding existing norms, disrupting the ecological balance, eventually leading to serious water scarcity and ultimately rendering the land uninhabitable in the future.

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Author Profile

Application of Artificial Intelligence in Green building Design

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Abstract:
Green building design is a result of carefully designed spaces which consider ventilation, daylight, energy, water, etc. To achieve green building compliance, simulations, calculations and different options are tested in software in order to take right decisions. The role of computer analysis plays a major role in decision making and shows the evidence of the favourable result achieved. When a building meets all the requirements of rating systems, it achieves a green building certification. Artificial intelligence is an advancement in Computer technology serving architects, engineer and designers a wide scope of work faster and reliable. Artificial intelligence (AI) applied to green buildings might be the answer to the global problems of sustainability. AI is the field of study and development focused on creating intelligent computers capable of reasoning, learning, communicating, planning, moving, manipulating objects, and solving problems. Artificial Intelligence (AI) offers several advantages, including the improvement of production and communication. This research focuses on the scope of Artificial Intelligence which can be helpful in green building design and compliance to rating systems. The methodology of the research is based on systematic review of Scholarly articles and literature to find the available tools, scope, applications, potential, current trends and future scope. The research study also explores literature in which artificial intelligence technology was applied or can be applied in green building design. The paper concludes with findings and discussion of artificial intelligence in green building industry.

Keywords:
Artificial Intelligence, Building Design, Green Building, Sustainability, Technology

Introduction

Green Building Design is achieved by multiple analysis of building performance in terms of energy, water, daylight, ventilation, and lighting, etc. Green rating systems such as GRIHA (Green Rated Integrated Habitat Assessment), IGBC (Indian Green Building Council), WELL, LEED (Leadership in Energy and Environmental Design), Green Star, Green Mark and BREAM (Building Research Establishment Environmental Assessment Method) provide standards, criteria or benchmarks in which points are assigned and accordingly rating is given to the building. The rating systems focus on a building's ability to achieve sustainability, energy efficiency, reduction in environmental impact, limit use of limited resources and rely on renewable sources, address climate change, and many more. Thus, to achieve a green rating the building design must undergo monitoring, multiple analysis and decision making based on analysis done. [5].

The research question is that what is the suitability of AI tools in green building design, what options are available, and what is their feasibility? Various software applications are used in analysis and simulation of building design. This software is capable of analysing climate, surface radiation, wind flow, daylight factor, energy consumption and artificial lighting. Software such as Autodesk, Sketchup, Rhino, DiaLux, Ecotect, IES VE, Design Builder, Energy Plus and suitable plugins of these software. The aim of the research study is to find out Artificial Intelligence tools which are useful for Green Building Design. The objectives of the study are to identify the available AI tools and there use in green building design, to analyze the viability of the software along with its benefits and limitations.

1. AI-Driven Approaches to Green Building Certification:

Artificial Intelligence (AI) is becoming an essential tool in green building design, fundamentally transforming the approach of architects and designers to sustainable construction. AI provides significant advantages in this domain, particularly by enhancing energy efficiency, optimizing material choices, and improving overall building performance. An important use of AI in green building design is the utilization of generative design algorithms. These algorithms enable architects to examine numerous design possibilities that adhere to particular limits and limitations. AI algorithms may utilize environmental data, energy usage trends, and other variables to produce inventive design solutions that priorities sustainability and energy efficiency. [12].

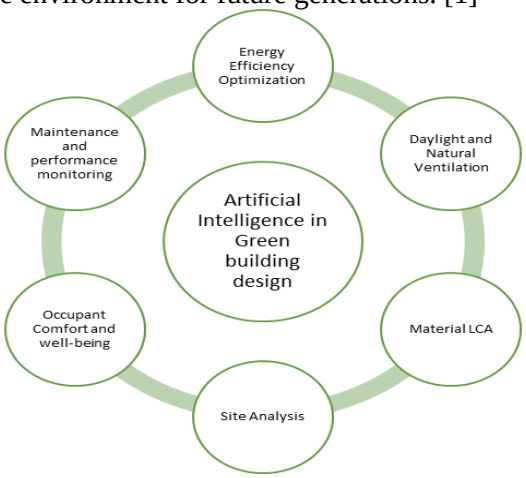
Furthermore, simulation tools driven by artificial intelligence (AI) are essential in assessing the

performance of buildings and pinpointing areas where enhancements may be made. These technologies have the capability to replicate elements such as daylighting, natural ventilation, and thermal comfort in order to enhance the quality of the interior environment while reducing energy usage. In addition, AI enables the conduction of life cycle assessments (LCAs) for building materials, assisting architects in making well-informed choices about material selection and construction techniques in order to minimize environmental consequences.

In addition, AI-powered systems allow architects to effortlessly incorporate sustainability ideas into the design process. These platforms offer immediate feedback and suggestions on design tactics, material selections, and building methods that promote energy efficiency. Through the utilization of artificial intelligence, architects have the ability to design buildings that not only reduce energy usage and carbon emissions, but also improve the comfort and well-being of the occupants.

The Integration Of AI In Green

building design signifies a substantial advancement in the development of sustainable and ecologically conscious constructed spaces. [12]. 3Through the utilization of AI algorithms and simulation tools, architects may create structures that not only fulfil present requirements but also make a positive impact on the environment for future generations. [1]



F1: Use of AI in green building design and analysis. Source: Author

Artificial Intelligence (AI) is essential for advancing sustainable architecture since it improves the design process, optimizes building performance, and enables well-informed decision-making. The following outlines the ways in which AI helps to sustainable architecture:

1. Energy Efficiency Optimization: AI algorithms incorporate building data, including energy consumption trends, weather conditions, and the occupant behavior, to optimize energy utilization and minimized inefficiency. Minimizing energy use and environmental effect by simulating different situations and suggesting energy-efficient design ideas.
2. Daylighting and Natural Ventilation: Artificial intelligence-powered simulations assess daylighting and natural ventilation methods to optimize the utilization of natural light and airflow in buildings. It is possible to optimize interior environmental quality and enhance occupant comfort by analysing building orientation, window location, and shading devices. This analysis also minimizes the requirement for artificial lighting and mechanical ventilation.
3. Material Selection and Life Cycle Assessment: AI tools evaluate the ecological consequences of construction materials across their whole lifespan, taking into account aspects like resource extraction, production procedures, transportation, and disposal at the end of their useful life. Life Cycle Assessment enables decisions that minimized embodied carbon and support circular economy concepts by offering insights into the environmental impact of various materials.
4. Site Analysis and Urban Planning: AI algorithms are beneficial to utilize geographic data, urban patterns, and environmental elements to provide insights for site selection, urban planning, and landscape design. Forecasting microclimatic conditions, evaluating the distribution of green spaces, and recognizing potential for using passive design solutions.
5. Occupant Comfort and Well-being: AI-driven building management systems monitor indoor environmental conditions, occupancy patterns, and user feedback to optimize comfort and well-being for building occupants. By dynamically adjusting HVAC systems, lighting levels, and acoustic conditions based on real-time data and user preferences, AI enhances occupant satisfaction, productivity, and health while reducing energy consumption.
6. Predictive Maintenance and Performance Monitoring: AI algorithms analyze building performance data, sensor readings, and maintenance logs to predict equipment failures, identify inefficiencies, and optimize building operations. By implementing predictive maintenance strategies and continuous performance monitoring, AI helps reduce downtime, extend equipment lifespan, and improve overall building efficiency and resilience.

2. Methodology

The research study employs a technique that relies on secondary data and a comprehensive evaluation of scholarly articles and journal papers. An extensive examination of the use and implementation of Artificial Intelligence techniques for the purpose of designing and certifying environmentally-friendly buildings. The study assesses several techniques for the utilization of AI in the design of environmentally-friendly buildings. Given that AI is a relatively new technical development, the research articles from the past five years will be examined. In addition, the official

websites of the software companies will be reviewed for information. Analysis and Inferences will identify the gaps in literature and summarize the findings.

3. Literature Review

A paper by I Alecrim, et.al demonstrates the integration of Building Information Modelling (BIM) and Life Cycle Assessment (LCA) offers a new approach to automate the evaluation of the impact on the environment in the building sector. [4] Although previous research has been conducted, there is still an urgent need to establish a universally accepted evaluation framework and suggested software tools for Life Cycle Assessment (LCA) inside the Building Information Modelling (BIM) approach. This study assesses the present condition of Life Cycle Assessment (LCA) integration in the Building Information Modelling (BIM) procedure and contrasts outcomes obtained from two LCA software tools: Athena Impact Estimator and Tally. The research examines the interoperability, user-friendliness, and environmental impact assessment capabilities of both technologies by using a case study created in Autodesk Revit. [4]
Tally exhibits exceptional compatibility and user interface, whilst Athena Impact Estimator showcases an extensive materials database and meticulous construction characterization prerequisites. [4] The research aims to quantify environmental impacts using selected indicators such as Global Warming Potential (GWP) and Acidification Potential (AP) by following the EN 15978 methodology, which includes material production, construction, use, and end-of-life stages, as well as the ISO 14044 standards for goal definition, inventory analysis, impact assessment, and results interpretation. (I Alecrim, et.al. 2020) This study highlights the possibility of improving Life Cycle Assessment (LCA) procedures by including Building Information Modelling (BIM), providing valuable information on choosing appropriate software and considering methodological factors for conducting thorough environmental impact assessments in building projects.

A paper by J. Q. Huda Mohamed Ibrahim El-Baz examines a case study of a Coastal Villa in New Damietta, Egypt, and Revit software with AI capabilities are used on zero-energy construction strategies in new cities. In light of global climate change, coastal cities must reduce non-renewable energy use. The project intends to offer urban zero-energy construction concepts by emphasizing clean, sustainable energy sources and their significance in environmental sustainability. The research uses Revit software and LEED standards to measure building energy efficiency to meet Egypt 2030 sustainable development targets. The research shows that zero-energy construction designs may reduce carbon emissions and provide environmental resilience via theoretical inquiry and practical implementation, including field tests and computer simulations. The planned Coastal Villa in New Damietta shows how passive architecture, renewable energy systems, and energy-efficient HVAC solutions can create a greener future. The research emphasizes the importance of multidisciplinary methods and technical advancements like AI-powered design tools in sustainable architecture and urban development environmental mitigation.

The research paper by Chen, Zheng & He, Yu. discusses the crucial problem of worldwide environmental pollution caused by the building industry and emphasizes the pressing necessity to reduce its negative impacts. [2] The project seeks to optimize green building techniques and mitigate environmental harm by utilizing artificial intelligence (AI) technology. The research examines various automatic control systems that can be applied in the design, construction, and operation of buildings by analyzing existing information models such as Building Information Model, Machine Learning, Deep Learning, Response Surface Methodology, Multi-Agent System, and Digital Twins. The research highlights the fundamental concepts of sustainable building, including optimal energy efficiency, efficient resource allocation, environmental compatibility, and ensuring resident comfort and safety. Furthermore, it emphasizes international benchmarks for sustainable building practices, such as China's GB/T50378-2014, and emphasizes the significance of integrating environmental factors into the stages of planning and construction. [2] The study recognises that while AI has the potential to improve environmental performance and energy efficiency in building, there are problems associated with cost implications and economic feasibility. However, the report highlights the need of using AI technologies to enhance the efficiency of green building design, construction, and operation processes. It also emphasizes the necessity for more research to investigate other combinations of information models for sustainable construction practices. The study provides significant insights and recommendations that contribute to the continuing discussion on green building. It highlights the crucial role of AI technology in tackling environmental concerns and promoting sustainable development goals.

4. Artificial Intelligence tools

Several Artificial Intelligence tools and platforms can be utilized for green building design, each offering unique capabilities and features. Following are the AI tools used in green building design:

5.1. Autodesk Generative Design:

Autodesk's generative design tools leverage AI algorithms to explore numerous design options and

optimize building performance, including energy efficiency and sustainability. Generative design uses input goals set by the designer and creates the design output. Autodesk has a large number of products. Out of all products, the AI powered design tools are identified with special focus on green building requirements. Autodesk Forma: It is a cloud-based software that performs Real time analysis of wind, energy and noise can be done using this software. The software is suitable for early-stage planning and design. The software provides time efficiency of 50-65% reduction in time required to develop conceptual design. The subscription cost is around INR 81,000/- for one year

Autodesk Infodrainage: InfoDrainage is a comprehensive design and analysis tool for stormwater drainage systems and hydrological simulations and cost effectiveness. Drainage design requires consideration of topography, construction materials, hydrological data. Display of real time animation and objects. The results obtained from input data can be exported in various formats. This software is mostly beneficial for floodline detection, pipe design, drainage layout, and storm water design. The subscription cost is around INR 2 lakhs for one year

5.2. Green Building Studio:

Green Building Studio, part of Autodesk's suite of tools, utilizes AI and cloud-based simulations to assess building performance and optimize energy efficiency, daylighting, and thermal comfort during the design phase. It assists in whole building performance analysis which compliances to the national codes of countries such as ECBC code of India. Whole building analysis includes thermal analysis, operational cost of building, climate, daylight and ventilation, form analysis: surface radiation, HVAC, Lighting, equipment heat gains, energy and water calculations.

5.3.Sefaira:

Sefaira is a cloud-based software platform that integrates with building information modeling (BIM) tools to analyze and optimize building performance in terms of energy, daylighting, and thermal comfort using AI-driven simulations. It is a plugin which can be used in Autodesk Revit and Trimble Sketchup software. Comparative analysis results are generated of conceptual design options and you can decide the best option. The results can be displayed in charts and tables. The software assists in identification of critical spaces of the building and solutions can be provided and enhanced design is possible. The software uses ASHRAE and other industry standards for simulation. The subscription cost is around INR 1.6 lakhs for one year

5.4. Tally – Autodesk Revit:

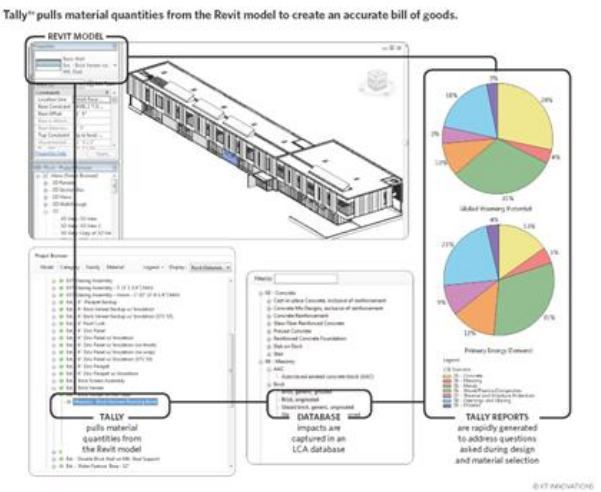
Life cycle assessment is used for analysing the performance of material from the manufacturing stage to the end or disposal. A material has significant impacts on the environment during its manufacture, use and disposal. Tally is an AI-powered tool that use life cycle assessment (LCA) to assist architects and builders in assessing the ecological consequences of building materials and construction techniques. This allows for well-informed choices to be made in order to reduce carbon emissions and support sustainability. Tally support Autodesk Revit software as Revit analyses each element as a material, it is easy to perform LCA simulations.

5.5. Honeybee:

Honeybee is an open-source platform that integrates AI algorithms with building performance simulations to assist architects and engineers in designing sustainable buildings with optimized energy usage and environmental impact. Honeybee software helps architects, engineers, and designers with advanced environmental analysis, modelling, and optimization for building design and urban planning projects. Honeybee integrates smoothly with Rhino and Grasshopper to study building performance indicators including daylighting, solar radiation, energy consumption, thermal comfort, and airflow dynamics. This comprehensive platform lets designers examine design alternatives and parameters to modify building designs, materials, and systems for sustainability and occupant well-being. Honeybee promotes LEED and BREEAM certifications by using data-driven insights and evidence-based decision making to ensure projects satisfy strict sustainability criteria and benefit the built environment. Honeybee encourages multidisciplinary cooperation, creativity, and energy-efficient, ecologically sensitive, and resilient buildings and communities with its user-friendly interface and tremendous capabilities.

5.6. Ladybug Tools:

Ladybug Tools is a collection of open-source plugins for environmental analysis and simulation in building



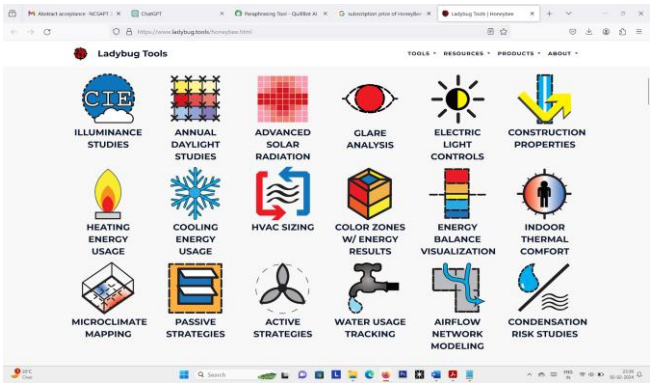
design. It includes AI-driven tools for daylighting analysis, energy modeling, and thermal comfort assessment to support green building design practices.

F2: Tally AI Building analysis

Source:

https://apps.autodesk.com/RVT/en/Detail/Index?id=3841858388457011756

Ladybird Tools is an accomplish Grasshopper and Rhino environmental analysis plugin used in architectural and urban design projects to optimize building efficiency. Solar radiation analysis, daylighting research, energy modelling, outdoor comfort analysis, and climate-based design optimization are its functions. Ladybird Tools helps designers make educated decisions and create performance-driven designs by simulating and visualizing environmental circumstances. By incorporating environmental research directly into the design workflow, Ladybird Tools helps architects and engineers explore design choices for more sustainable, energy-efficient, and pleasant buildings. Its user-friendly interface, extensive library of analysis components, and seamless integration with Grasshopper make it essential for professionals looking to improve design quality and environmental performance while meeting sustainability goals and regulatory requirements.



F3: Analysis which can be done by Ladybug tools

Source: https://www.ladybug.tools/

5.7. Sidewalk Labs:

Sidewalk Labs' AI software aims to transform urban planning and development by utilizing artificial intelligence to establish cities that are more efficient, sustainable, and focused on the needs of people. The program combines data analytics, machine learning, and predictive modelling to enhance several elements of urban living, such as transportation, energy consumption, trash management, and community involvement. Sidewalk Labs' AI software utilizes extensive data from sensors, IoT devices, and urban infrastructure to discern patterns, trends, and insights, which may be used to guide decision-making and policy development. The advantages encompass the capacity to augment mobility and accessibility, diminish environmental repercussions, increase public services, and cultivate inclusive and dynamic urban communities. Through the use of AI-generated insights, urban planners and politicians may make informed decisions based on data to tackle intricate urban issues and develop cities that are more habitable, environmentally friendly, and adaptable to future uncertainties.

5.8. Click Up:

It is a productivity and project management tool, employs artificial intelligence (AI) to enhance its functionality and optimize user experience. AI systems streamline repetitive tasks, enhance operational efficiency, and provide tailored recommendations by analysing user actions and preferences. Click Up's AI is useful in efficient project management. Click Up's user-friendly interface and AI-driven features enhance team collaboration, visibility, and adaptability, hence enhancing project results and organizational effectiveness.

These AI-powered tools and platforms empower architects, designers, and engineers to make informed decisions, optimize building performance, and create environmentally sustainable structures that contribute to a more sustainable future.

5. Benefits of use of Artificial Intelligence tools studied above:

- Supports sustainable development and green building goals
- Provides ease of work and understanding for new learners.
- Plugins can be used with existing software which are already being used in the Architecture and construction industry. This saves additional skill requirement.
- Data analysis is easier to interpret in forms of graphical representation
- The results can be exported in desired format required to submit to the green building rating system.
- Complex calculations and management are easy to handle and data is reliable.
- AI driven tools have standards such as ASHRAE and other standards preloaded into the software, this helps in designing to the requirements with minimized errors.

6. Limitations of use of Artificial Intelligence tools studied above:

- Latest graphic card requirements generally past 3-4 years are eligible.
- Requires monitor resolution.
- Cloud based software require high internet connectivity.
- Artificial Intelligence Plugin tools require latest versions of parent software

7. Future Need of Development in AI for Green Buildings

- Educational Versions of AI tools are required. Free trials must be available for use.
- There is need of AI in enhancing the efficiency of green buildings during construction and operation phase. Evaluation at this stage needs to be developed.
- AI driven tools for sustainable construction practices
- The user interface should be simple and universal as there is lack of skill.
- Linkage between multiple software is essential
- AI needs to enable comparative analysis with more easy graphical understanding.
- AI compatibility with various software is required.
- Need of AI plugins to parent software reduces cost and time for extra learning. If the software is separate, it must consist whole building analysis, thus it will be economical for subscription purchase.
- Cloud based AI tools must support previous versions of computer configurations.
- AI needs to detect errors in design and provide suggestions.
- Generating reports for Green Building certification will be additional benefit.
- AI tools must link with Google Earth for site analysis and real time data.
- BIM is emerging as a technological advancement; thus, BIM and AI must collaborate and develop with compatibility to each other.

8. Conclusion

The research study reviewed secondary data, official websites, guidelines, product specifications, and scholarly papers to emphasize the significance of AI-driven technologies in Green Architecture. The article provides a comprehensive guide for architects and green building consultants to investigate the current alternatives by explaining each tool in detail. Architectural work is a perpetually demanding task, and including green building research increases the workload, resulting in additional time requirements. As the duration of project design increases, it becomes less cost-effective. Optimizing time efficiency is important in the process of construction design and implementation. AI tools function as time-saving devices while also improving the precision of projects in attaining green construction objectives. The study indicates that AI is increasingly seen as a crucial instrument for decision making in the design and analysis of green buildings.

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Considerations For Climate Responsive Façade Design In Tropical Climate For A Commercial Building

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Abstract:
One of the largest energy loads in a building is due to envelope gains and losses. Limiting these loads will improve energy performance and improve occupant comfort. This applies primarily to air-conditioned spaces however relevant to naturally ventilated spaces too. Globalization has affected the design of façade with respect to materials and technology. Ideally the façade design is a result of through study based on climate, orientation, radiation etc. But currently the prominent or the road facing side is highlighted using complete glazing which is not effective in Indian Tropical climates. Each façade receives different amount of radiation, wind exposure etc. and hence the design of each façade needs to be done taking this into consideration Microclimate considerations should drive the decisions in design of openings. The aim of the study is to suggest climate specific considerations for a commercial building in warm climate. Objectives of the study are to study hot or warm climate, to use tools like radiation chart, bioclimatic chart and wind rose to understand climate parameters pertaining to a single orientation, to study opening design and shading devices in warm climate, to provide a climate responsive approach towards architectural design. As case examples two conceptual climate responsive façade designs in two different climatic zones and assess their workability Method used is secondary literature review to understand climate and passive solutions. Proposed outcome is to give climate responsive suggestions and present a conceptual façade design and shading devices for the south side façade in warm climate.

Keywords:
Orientation, Radiation, Opening, Shading Device.

Introduction

Commercial buildings consume majority of the energy needs in building sector. Demand for cooling a commercial building is high and it will go on increasing in near future as city temperatures are rising too. (Prieto A et al, 2018). The building element which contributes most to the energy load of a building is the envelope. The envelope essentially comprises of the walls and the roof. The wall element being the most critical element to control the heat gain of a building must be designed so. Currently it is seen that most of the commercial buildings incorporate a completely glazed façade, which for the climate of India is not appropriate. The façade design should be a result of many considerations like climate, building orientation, materials etc. If due importance is given to façade design it can help reduce the energy intensity of a building. *A fabric first approach to façade design can help reduce air conditioning loads.* (Napier J, 2015).

The façade, which is the face of the building has many elements which need relevant design consideration. The façade orientation, Wall to window ratio, shading devices, choice of building materials etc. are facets which one needs to consider while designing a façade. The orientation determines the amount of solar exposure, building materials control the heat transfer and wall to window ratio restricts the heat gain. These are just a few aspects that are critical in façade design. When a façade design is aimed at being climate responsive, there are certain aspects of building design which are vital. The aim of this research is to understand the consideration designers need to make when designing a climate responsive building façade. Application of Passive strategies are the first step towards achieving energy efficiency. (Olgyay V, 1963). The scope of this research would be to understand the considerations for designing a climate responsive building façade.

1. Methodology

When one designs a climate responsive façade there are some aspects which need to be understood before any design decisions are taken. These aspects play a vital role. The objective of this paper is to understand what aspect are crucial and then the application of these aspects would be explained through two case examples. The intention was to identify the elements of climate responsive design and to create a conceptual design of a climate responsive façade to be constructed in warm climates (Goa and Jodhpur) which are oriented in south west and analyze its effectiveness towards the conditions prevailing in the city. The tools used are from bioclimatic chart, wind rose, radiation chart to find out Horizontal shading angles (HSA) and Vertical shading angles (VSA) for south side of a mall. A hypothetical plan and facade is taken as base case and a retrofit design to improve the façade design is proposed

by applying passive design techniques. The parameters considered are position of openings, types of openings, shading device types, wall material, surface colour and texture choices, use of vegetation etc.

2. Literature Review

Aspects to be considered for designing a climate responsive facade: (Alejandro Prieto, 2018)
a. Orientation
b. Sun angles
c. Façade materials
d. Ventilation

3.1 Orientation

Façade orientation plays a very critical role in restricting the heat gain, creating better daylight spaces. (Alejandro Prieto, 2018). It has been proven that the best façade orientation would be north, which receives ample diffused light throughout the day without any direct solar radiation. The south having direct solar exposure, still is quite easy to shade with horizontal projections. The east and the west orientations are quite difficult to shade as the incident solar angle is low. (Napier, 2015). To understand the amount of radiation falling on each façade orientation, radiation square can be used. A radiation square provides the used with the incident solar radiation throughout the day over the twelve months.

3.2 Sun angles

Understanding the incident solar angles on a façade helps in designing the solar shading. These solar angles are the azimuth angle and the altitude angle of the sun which are further required to calculate the Horizontal and vertical shading angles (HSA and VSA). (Matusiak, 2006). The horizontal shadow angle (HSA) is used for vertical shading devices. It's the angle between the normal of the window pane and the azimuth of the sun.
HSA = azimuth - orientation
The vertical shadow angle (VSA) is a little bit more difficult. If we imagine a virtual plane between the bottom left-hand and right-hand corners of the window and the sun, then the VSA is the angle this plane forms with the ground plane. The VSA is required when designing horizontal shading devices such as overhangs. (Comfortable Low Energy Architecture, n.d.)
VSA = arc tan (tan(altitude) / cos (HSA))
(https://www.newlearn.info/packages/clear/visual/daylight/analysis/hand/shadow_angles.html)

3.3 Façade materials

There are various materials that can be chosen when designing a façade, but when it comes to climate responsive façade design the U value and the transparency of the materials become critical. Thermal transmittance (also known as U-value) is one of the most significant properties which define the energy behaviour of a building envelope. *The U-value is understood as the amount of heat which flows through a certain element per unit area and time. Hence selection of the materials with low u-value will be most efficient.* (David Bienvenido-Huertas, 2018)

3.4 Ventilation

A façade design which caters to natural ventilation in a building will automatically be effective in reducing the heat gains of the structure. (Alejandro Prieto, 2018). In climates where the humidity is high, cross ventilation is a very effective technique but whereas climates which have dry conditions, with dust, there its becomes necessary that the wind needs to be blocked. (Ahmed, 2014) (Tariq Ahmed, 2021). Understanding the climate requirements and use of tools like wind rose which help in assessing the wind direction and speed, are helpful in making the precise design decisions. (Titin Sundari, 2017)

3. Climate response

4.1 Responses to warm and humid climate

For a warm humid climate zone following are the strategies to be incorporated in a building for attaining comfort. Minimise heat gain (shading) and maximise effective cross ventilation. Large windows fully openable equipped with flexible louvers allowing a regulation of ventilation. The fenestration height should be such that there is a good distribution of air flow over the human body. The plant cover reduces reflected radiation and lessens the heating up of the surfaces. Trees casting shadow help minimise south radiation and can be employed to maximise airflow. Highly reflective surface with good resistive insulation. The wall surface is painted with light pastel shades or whitewashed. Lightweight materials with low absorption of radiation on the outside with protected walls. To avoid direct solar radiation and glare, overhangs should be shaded by an overhanging roof, screens, lattices, grills etc. Pergolas obstruct the vertical radiation and greenery to absorb afternoon sun radiations and allow windflow. (Krishnan A, et al, 1999)

Table 1: Calculation of angles as per solar chart of goa

Month	*Time*	*Altitude*	*Azimuth*	*HSA*	*VSA*
January	11 am	45	147	-33	50.02
	1 pm	50	190	10	50.79
	3 pm	38	223	43	46.12
April	11 am	63	113	-67	37.41
	1 pm	75	207	27	79.20
	3 pm	52	258	78	80.60
	11 am	58	130	-50	68.13

October	1 pm	70	193	13	71
	3 pm	52	243	63	72

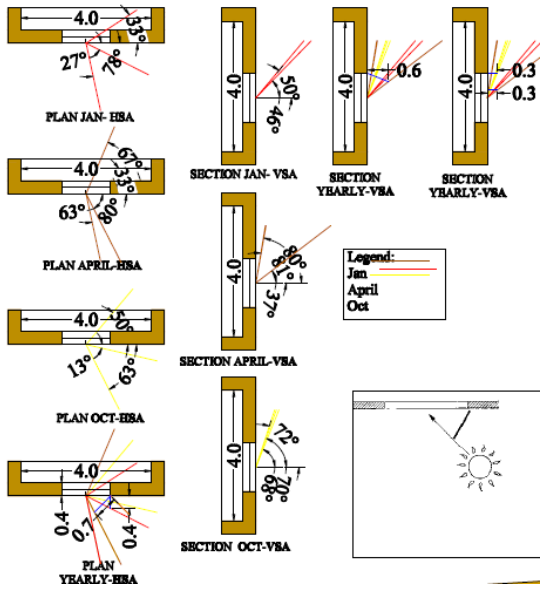


Figure 1: Calculation of HSA & VSA

F1:: Radiation square of south side Goa (Source: Kolhatkar)

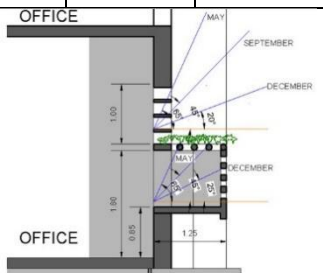
4.2 Response to hot dry climate

For a hot dry climate zone following are the strategies to be incorporated in a building for attaining comfort. Extremes of heat & dryness, leads to high outside temperatures and hence the sun needs to be cut off. Intense sun, also reflected from ground & surrounding buildings leads to glare, hence the glare has to be reduced. The high day time temperature and rapid cooling at night may cause materials to crack and break up hence proper selection of local materials is necessary. Constant low humidity, leads to human discomfort hence humidifying the wind is necessary. In this climate, it is imperative to control solar radiation and movement of hot winds. Cross ventilation: replace hot dry air by cooling. Cooling in hot season, by using wind catcher/ wind tower and heating during cold season, by earth-tunnel system. Openings and windows are necessary for natural lighting and ventilation, but heat gain in summer should be minimal. Windows and other openings must be placed in suitable positions in relation to the prevailing (cool) breeze to allow a natural airflow through the building, to achieve air movement across the body for evaporative cooling and air changes for driving out excess heat. Flies, sand, dust storms are a nuisance. Breeze cannot be used directly unless cooled and made dust free. Surfaces exposed to the sun should be reduced as much as possible to reduce heat gain through envelope of the building. The high day time temperature and rapid cooling at night may cause materials to crack and break up. Use of shading devices to cut off incident solar radiation so the harmful radiation is cut off before entering the building. Projecting roofs, verandah, shading devices, trees, arcades, colonnades and small enclosed courtyards. (DeKay M, Brown G, 2001) Flexible Spaces- One of the common passive shading device features is a balcony whose upper portion is effectively used as a winter living space and at the same time provides adequately shaded buffer spaces below to create comfort conditions during summer. Surfaces exposed to the sun should be reduced as much as possible. Resistance insulation-use of reflective surface on both the roofs by use of light colored or shiny polished metal. Mass that is well shaded, light in color and ground coupled.

Solar radiation which is received on the west and east sides is highest as compared to north and South side. Also, the protection of walls by providing horizontal shading devices is easier to the north and south side. Amongst the all four directions west side receives maximum radiation after the roof. Hence South west façade is the study focus in this research paper.

Table 2: Calculation of angles as per solar chart of Jodhpur

Month	*Time*	*Altitude*	*Azimuth*	*HSA*	*VSA*
May	12 pm	75	143	-82	-88
	2 pm	68	243	18	69
	4 pm	40	267	42	48
September	12 pm	70	153	-72	-83
	2 pm	62	230	5	62
	4 pm	40	258	33	45
December	12 pm	40	173	-52	-54
	2 pm	38	210	-15	-39
	4 pm	20	233	8	20



F2:: Section representing shading angles

F3:: Radiation square of south west side Jodhpur (Source: Kolhatkar)

4.3 Climate Determinants

While studying the warm climate zone climate of two representative cities have been studied further Goa (warm humid climate zone) and Jodhpur (hot dry climate zone). Description of the climate of Goa and Jodhpur has been explained further with charts and tables. The climate determinants taken into consideration are temperature, wind, humidity, radiation, sky conditions, rainfall etc.

Mean Temperatures, Relative humidity levels and Precipitation are high. The wind velocity is generally low except during rain squalls, when usually one or two dominant wind directions prevail. In coastal regions, however, regular thermic winds provide relief from heat and humidity. The sky is fairly cloudy throughout the year in coastal regions, however, it is often clear. Accordingly, the solar radiation is to a great extent diffused and partly reflected by the high vapor content. Generally, overcast causing unpleasant glare. In warm climates the radiation is mostly directional and the shadow angles can be established with a high degree of accuracy.

The architecture of Goa is a combination of Indian, Mughal and Portuguese styles. Dramatic and startling color plays an important role in Goan Architecture. Color was decorative and used purely to create a sensation. The walls were made of mud and then later of laterite stone. They were usually plastered then painted. Very few buildings are colored exactly alike and solid colors are used for front facades.

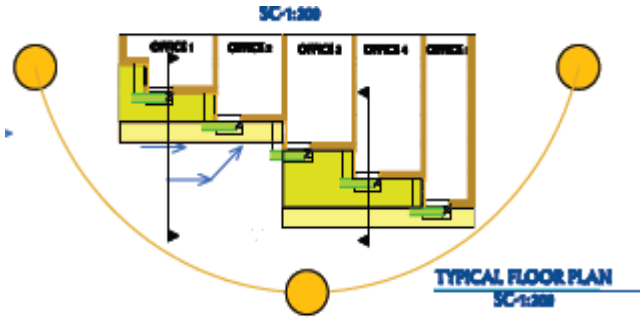
Hot and dry Jodhpur

Characteristics of climate determinants are- Summer mean temperatures are high, Relative humidity and Precipitation are low, Winds are hot, carrying dust, Cloudless clear skies, glare causing. Jodhpur Climate is of an extreme type, with the variations in temperature range being very high. Weather in Jodhpur, Rajasthan is dry and hot, a typical desert weather. The average annual rainfall is approximately 32 cm. In summer, the maximum temperature is around 42 deg and the minimum temperature is around 37 deg C. In winters, the maximum temperature is around 27.5 deg C and the minimum temperature is around 15.5 deg C. The annual temperature graph signifies that there is large diurnal temperature; especially in the month of May. Therefore, the advantage of the lower temperature in the night can be cool the building in night. Direct solar is high throughout the year but relatively lower diffused sunlight. Glare has to considered while designing. The wind rose denotes the prevailing wind direction to be south west i.e., perpendicular to the façade orientation. Catching the wind inside the building should not be a problem, high particulate matter in the wind has to be catered to. This wind direction continues to be south west throughout the year. As the façade faces south west, it is very essential to evaluate the amount of radiation for that orientation. As seen in the radiation square the maximum radiation is received in November in the noon. Therefore, while assuming the shading devices for this month and time has to be critically analyzed. Having considered that, it can be seen that even though November gets most radiation, it's for he least no. of hours. January follows the same trend, but lower than November. Also, the period for which the façade receives sunlight is more for the summer month's i.e. April may June. Larger duration of exposure results in higher heat gain and an additional glare problem throughout the day. The month of august receives least radiation for the least no. of hours. According to the radiation square May and December have varying radiation pattern and hence they have to be critically examined. First and fore most the shading devices have to be calculated.

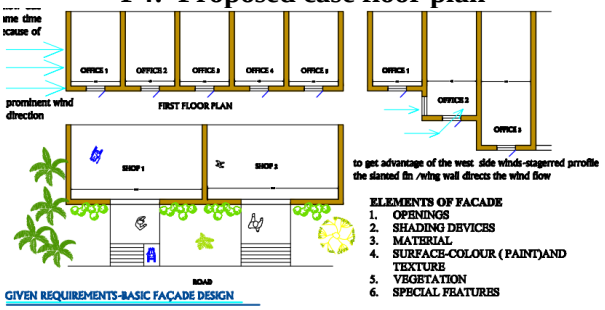
4. Design Alternatives

5.3 Case 1 South west façade mall Design Goa

The opening or the window requires protection from radiation, only from two sides. The horizontal projection required is quite less but considering the high rainfall in the area it is advisable to tilt it to cater to rain as well as sun. Diverting the wind by vegetation and structural arrangements is done. Windows designed to deflect breezes from varying angles. Wing walls in the form of vertical fins create positive pressure on the window and enhance the wind improvement. Siting and orientation- positioned to take maximum advantage of prevailing wind directions from west side. Trees casting shadow near the lobby of mall help in minimizing south radiation. An overhang's size is effective in shading most of the wall are from high altitude sun. Shading is achieved through plantation, vertical and horizontal devices. Slanted vertical fins are more effective than fins perpendicular to the south facing windows. Sloping *chajja* absorbs less heat than flat *chajja* due to its shape and less exposure to solar radiation. Bamboo pergolas with creepers is provided at the entrance. Prevention of solar heat gains requires not only eaves or overhangs but preferably shading the entire building envelope, which can be done with vegetation and by self-shading. Load bearing structure is built in locally available laterite stone which supports concrete slab.



F4: Proposed case floor plan



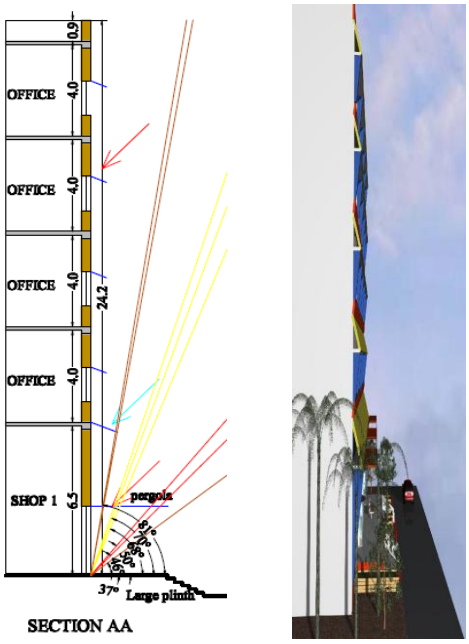
F5: Base case floor plan

F6: West Facade design with wing wall

5.4 Case 2 South West Façade mall design Goa

Following climate responsive strategies have been applied- Light colored shading and paving. Inclined continuous horizontal shading device as per the angles calculated above. So, the effective opening area window remains huge due to continuous shading. Fenestration areas are large to facilitate ventilation. Thus, vision window and ventilation window are is not compromised while handling shading needs. Generous shade for direct and diffused radiation is provided. Large overhangs protect the walls and openings from radiation and precipitation. Thus, the wall is also shaded. Maximize air movement and reduce radiant heat to occupants. The outer surface is reflective, light colored. Intermediate repeated inclined supports add to the elevation treatment. Green planter edge is created at the sill level which aids in cooling the air while entering. It is very important that shading devices are used more as functional feature and not aesthetic.

F7: Inclined façade design



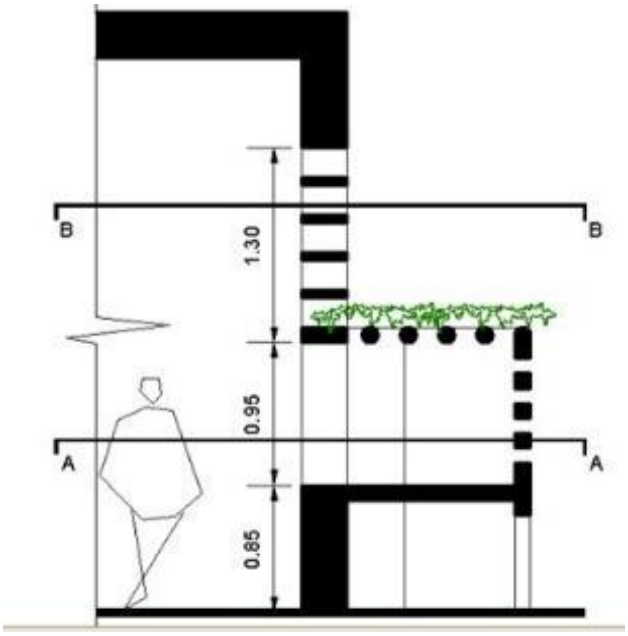
F8: Section with angles Figure 11: Slanted façade

5.5 Case 3 South west façade mall design Jodhpur

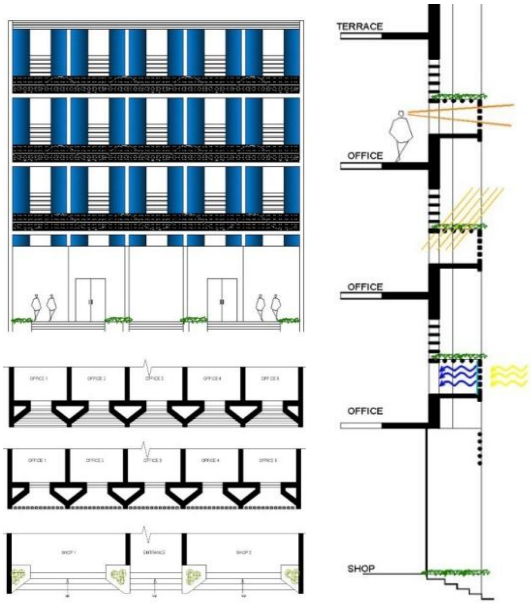
The design problem involves designing façade for an office + commercial building, which responds to the climate. The occupancy in the building is to be during the day time i.e., from 9 am to 6 pm. This is the time when the façade suffers maximum heat gain.

Design considerations include the following- The design in corporate shading from sun, protection from dust particles, humidifying air. As the whole façade is not possible to be shaded on the ground floor 2/3rd of the face is shaded for September heat. No shading is provided for December sun. Cylindrical pipes are provided as shading devices. So that it does not add volume to the building. The building is protected from the environment by a double skin which is derived from a traditional building element called the '*jaali*' which is prevalent in Rajasthan architecture. The double skin acts as a thermal buffer between the building and the surroundings. The shading for the opening is deliberately taken in a funnel shape, so as to let more wind enter the building. The outer skin sits 4 feet away from the building and reduces the direct heat gain through fenestrations. Drip channels running along the

inner face of the *jaali* allow for passive downdraft evaporative cooling, thus reducing the incident wind temperature. For the office floors visual connectivity was maintained. During the night when the desert temperature drops this floor slowly dissipates the heat to the surroundings keeping the area thermally comfortable. This time lag suits the staggered functioning of the building. Highly textured walls have a portion of their surfaces in the shade. The radiation absorbing area of such a textured surface is less than its radiation emitting area and therefore it will be cooler than a flat surface. The materials used for construction are a mix of local stone, steel, glass and concrete chosen keeping in mind the climatic needs of the region while retaining the progressive design intent.



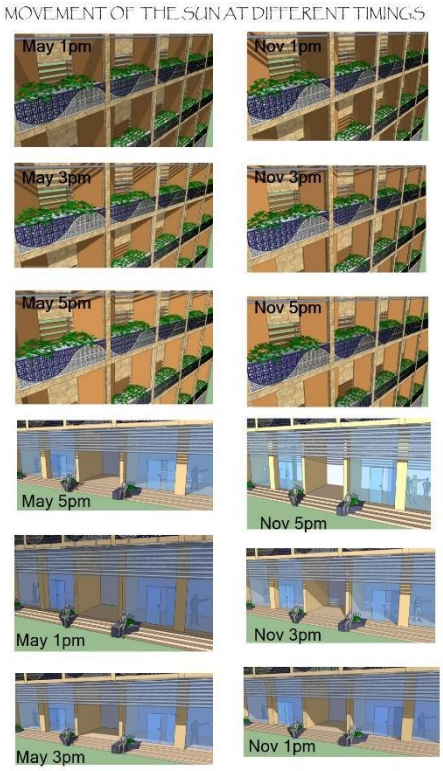
F9: Section showing jali



F10: Part plans and elevation Figure 15: Section showing shading, wind flow & visual connectivity

5. Conclusion

The paper represents applications of passive design strategies for one faced of south west orientation. It demonstrates that high energy intensive building types like malls and offices can have an approach in the facade design driven by the existing climate determinants which is very climate and context specific. The design explorations explicitly demonstrate the use of passive strategies in one building type at one orientation. Alternatives to one orientation are displayed. Similar methodology can be applied in other climate types with different faced orientations. Issues of climate identified in this paper can be used as a tool for assessing similar buildings in future.



F11: Sun movement

6. Acknowledgement

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Exploration Of Ancient Paanpois In Western Maharashtra.

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Abstract:
Paanpois (public drinking water dispensing units) were erected on the passenger, merchant and pilgrimage routes from long ago. The water here is distributed for charity. Devotees used to drink water at such places and move forward. A Paanpoi typically consists of a chamber made up of two carved entrance pillars in solid basalt rock and stone walls built behind them. The roof is constructed by piling stones on top of one another without the usage of cement or lime mortar. It houses one or two Ranjan (water storage pots made of stone). These Paanpois are perceived by the local people to be ancient toll booths or temples and sometimes they are just lying simply ignored which lead to them being buried or defaced or broken. The paper aims to explore the history and importance of Paanpoi, how it works and mapping of Paanpois in Maharashtra. In this paper the author will be discussing instances of eight such structures from Pune, Satara, Shrigonda taluka and Aurangabad. Their provenance and other pertinent details will also be discussed.

Keywords:
Paanpoi, Ranjan, Explorations, Shrigonda, Pune, Satara, Aurangabad, drinking water dispensing unit.

Introduction

Paanpoi is a charitable arrangement practiced since ancient times to provide 'drinking water' to pilgrims during hot summers. It is a unique and ancient charity system to provide free drinking water to pilgrims during the hot summer months of India. This practice has been followed for centuries in various parts of India and has cultural and historical significance.

Paanpoi is a combination of two words - *'pani'* (meaning water) and *'poi'* (meaning bread). This practice is prevalent in regions where pilgrims travel long distances to reach holy shrines or temples and water sources are scarce. Paanpoi is an excellent way to provide comfort and support to these pilgrims, who are often tired and dehydrated after a long walk.

1. History

The practice of *Paanpoi* is ancient and has been practiced in India for centuries. It is a part of Indian culture and tradition and is practiced in different parts of the country. The history of *Paanpoi* is not entirely clear, but it is believed that the practice originated from the teachings of great Indian sages and saints who emphasized the importance of charity and service to humanity.

Paanpoi was popular even in medieval times when India was ruled by kings and emperors. Many kings and rulers of those times used to provide free drinking water and food to the poor and needy, especially during times of drought or famine. The practice was also seen as a way to gain the blessings of the gods and the goodwill of the people.

Paanpoi is a simple and effective way of providing free drinking water to pilgrims. Arrangements are often made near highways or routes that pilgrims take to reach holy shrines or temples.

Paanpoi water is often drawn from wells or other nearby natural sources. Then the water is stored in large vessels kept in the shelter. Pilgrims can then drink water directly from the pots or use small bowls to drink water. In some places, food such as bread, fruits or other snacks are also distributed to the *Paanpoi*. This practice is especially prevalent during festivals or special occasions when a large number of pilgrims visit holy shrines or temples.

In modern times, water pots are kept under temporary structures. Such modern *Paanpoi* are prevalent in various parts of India, especially in regions where the summer months are particularly harsh and water sources are scarce.

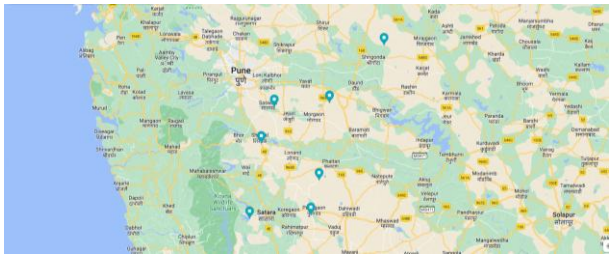
2. Objectives of the Research

- Mapping of *Paanpois*. (Figure 1)
- To study the architectural characteristics of the *Paanpois*.
- To study people's perception of *Paanpois*

- To study the threats to the *Paanpois*

3. **Research Methodology**

- Exploration and Documentation.
- Use of modern technology, such as photography, Google Earth Pro, and GPS to map and document the Paanpois in Maharashtra.
- Interviews of local people.



F1: Map showing locations of seven Paanpois documented in Pune, Satara and Shrigonda taluka.
Source: author.

Results

5.1 ***Paanpoi*** **at Shirwal, District Pune**

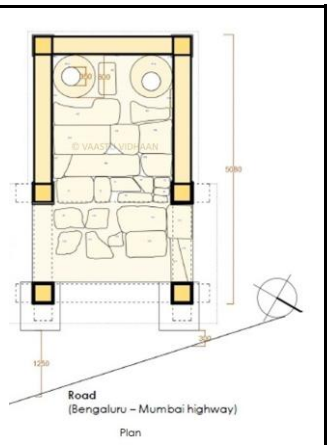
This 13th Century *Paanpoi* is located on Naigaon junction on the Pune Banglore highway (Figure 2). It is built in the Hemadpanthi style of architecture [1],[2]. It is facing North-East. It is referred to as *Seetechi Paanpoi* by local people. The *Paanpoi* (18.1206147,73.9839588) at Shirwal is unique in its form, architecture, and design. The chamber is made up of two carved entrance pillars in solid rock and stone walls built behind them. Additionally, the roof is constructed by piling stones on top of one another. It houses two water storage pots also known as *Raanjan* in marathi (Figure 3). Such systems were common on trade routes in Maharashtra's Western Deccan region. The primary asset of the architectural form is the social and cultural value that it conveys through the concept of providing a service to others. It is built in basalt stone ranging over a height of 300-600mm. The structure is very simple and the crux of it completely lies in the interlocking of stones.This construction has been done without using any binding material like lime or cement.

F2: Paanpoi at Shirwal, District Pune
Source: author.

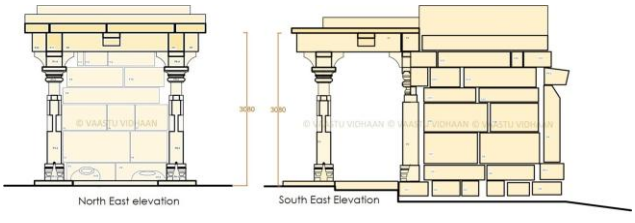
F3: Two Raanjans inside the Paanpoi at Shirwal, District Pune
Source: author.

This ancient *Paanpoi* was obstructing the road widening work of the six lane Pune Banglore highway (Figure 4). Accordingly, the Archeology Department informed the Highway Authority about the restoration of *Paanpoi* for its preservation. Hence, the Highways Authority has placed this *Paanpoi* in the middle of the road and has made a highway on one side and a service road on the other side. It has been demanded in the statement that the land should be acquired along the *Paanpoi* highway and its reconstruction should be done at that place. Architectural documentation of this *Paanpoi* has been done by an architectural conservation firm named Vaastuvidhaan Projects (Figure 5,6).

F4: The Shirwal Paanpoi obstructing the road widening work of the six lane Pune Banglore highway
Source: author.



F5: Ground floor plan of the Paanpoi at Shirwal, District Pune
Source: Vaastu Vidhaan Projects



F6: Elevations of the Paanpoi at Shirwal, District Pune
Source: Vaastu Vidhaan Projects

5.2 ***Paanpoi*** **at Kumbharvalan village, Saswad, District Pune.**

Kumbharvalan village (18.3498505,74.0703221) is home to a variety of memory stones like *Veergal* (hero stone), *Gadhegal*(Ass curse stone) and *Gajalakshmi* sculptures. Kumbharvalan village is known for one more historic structure i.e. *Paanpoi*. This *Paanpoi* (18.3421396,74.0681571) was located opposite Bhairavnath Temple in Kumbharvalan village and reported by Murlidhar Chandane (Figure 7).

	
F7: Paanpoi at Kumbharvalan, Saswad, Pune Source: Murlidhar Chandane.	**F8: Shri Pandaveshwar Mandir, Pandeshwar, Pune Source: author.**

There is a square shaped base on the plinth of the *Paanpoi* to keep the water pot. The size of this base clearly indicates that the water pot must have been huge. In due course of time, the big pot of water (*Raanjan*) has disappeared. The water features on this walkway suggest that it must be of utmost significance. This route departs from Pandeshwar and travels via Jejuri, Kumbharvalan, Saswad Village, Narayaneshwar Temple and Shirwal. Further this path joins the Khambataki Ghat. There is a very beautiful temple named after the Pandavas in the village of Pandeshwar (Figure 8). There is an ancient stepwell (18.017972,74.0108371) in the Khambatki ghat (Figure 9)

	
F9: Ancient stepwell in Khambatki ghat. Source: author.	**F10: Paanpoi at Supa Village Source: Pravin Shrisunder.**

5.3 **Paanpoi at Puhi ghat, Supa Village, District Pune**
Emperor Shahaji had entrusted the Jahagir of Pune and Supe Pargana to his wife Jijabai and his son Shivaji. Supe village can be reached from Pune-Solapur road via Patas. There is a small village called Kusegaon on the Patas Supe road. Supe village is four km ahead of Kusegaon. After coming from Patas, crossing the village called Kusegaon and coming to the south, there is a small ghat called Puicha Ghat. The *Paanpoi* (18.3650309,74.4187136) is located between the trees on the left immediately after climbing the ghat (Figure 10). It was reported by Pravin Shrisunder and Sameer Gejage.This is a north-facing Yadava period *Paanpoi* on the top of the Puhi Ghat road. The structure here has stone walls on three sides and an entrance on the north side. The construction of the *Paanpoi* is done by grinding stones to the right shape and stacking stone on stone without using lime or cement (Figure 11). There is a stone *Raanjan* (water pot) inside the structure (Figure 12). The *Raanjan* at Puhi, the Ranjan in Nane Ghat and the stone *Raanjan* in the Shri Narayaneshwar temple near Purandar fort show some similarities. This *Paanpoi* is currently in a dilapidated state.

	
F11: Interiors of the Paanpoi at Supa Village. Source: Pravin Shrisunder.	**F12 :Water pots inside the Paanpoi at Supa Village. Source: Pravin Shrisunder.**

5.4 **Paanpoi at Puhi junction, Shrigonda Taluka, Ahmedagar district.**
The remains of a Paanpoi (Figure 13) can be seen on the Puhi junction (18.712815,74.7645297) on the road connecting Shrigonda taluka of Ahmednagar district to the village of Bhangaon[3]. This junction was originally known as 'Poi phata'. Over the period of time, the name has been corrupted to Puhi phata (junction/ cross road). Currently it is in a dilapidated state. Ruins of large stone steles with beautiful carvings are lying next to this structure.

Ten stepwells were constructed in Shrigonda Taluka during the reign of Ahilyabai Holkar namely - stepwell at Khandoba Mandir, stepwell at market place, stepwell at college premises (does not exist anymore), stepwell at Holkarwada ,4 stepwells at Mandavgan ,stepwell at Shrigonda- Mandavgan, stepwell at Pethgaon [4]. This *Paanpoi* was also built during the reign of Rani Ahilya Devi Holkar. This *Paanpoi* was a part of the water system set out in Shrigonda by Ahilya Devi Holkar.

This *Paanpoi* is located at the junction connecting four villages namely: Deulgaon, Pisore Khaand, Bhangaon, Taakli Lonar. Stepwells were constructed in these four villages during the reign of Mahadji Shinde and the water from these stepwells was used in this *Paanpoi*. Drinking water facility was made available in this structure for Soldiers, spies, travelers, horses and other animals.This structure was also used by the soldiers to hide and keep an eye on the enemies. A similar structure has been spotted at Gosaviwadi near Mandavgan and reported by Rajesh Ingale.

	
F13: Paanpoi at Puhi junction, Shrigonda Taluka, Ahmedagar district. Source: Rajesh Ingale	**F14: Paanpoi at Jakhangaon, Satara district. Source: Kumar Gurav.**

5.6 Paanpoi at Jakhangaon, Satara district

Jakhangaon (17.6492802,74.3186697) is a village on Visapur-Aundh road in Satara district of Maharashtra. This ancient structure (figure 14) is standing on the right side at a distance of 1 km from Jakhangaon towards Visapur(17.6882905,74.3009564) in Satara District. This entire area is known as '*Powai Cha Mal*'. This structure was reported by Mr. Kumar Gurav and the information was shared by a localite named Nilesh Pandit. Elderly people from the village have been saying, earlier there were five such stone pavilions. Each pavilion had a stone pillar. Four out of the five stone pavilions could not withstand the test of time due to negligence by local people and they were buried under the ground. Some say that the stones of these four structures were buried in the work of water conservation. Currently the columns of this structure have been smeared with white and red paint. Now there is a fear that this structure will be demolished during road widening.

It is said that the structure that stands today used to house Shivlinga. This Shivling was known as 'Povaishwar'. But now what is worshiped as Shivlinga is not a Shivlinga but the remains of another stone pavilion. (The inner member of the lower portion of a stone roof) This road on which this structure lies, connects the villages of Aundh and Kinhai. The palanquin and procession of Goddess Yamai Mata of Aundh village goes through this route once a year and ends at the temple of goddess of Kinhai at Sakhargad. The devotees from the village mentioned that the pilgrims of this palanquin and procession took a short break at this ancient historic structure while moving towards Sakhargad. The names *Powaicha Maal, Povaishwar* are synonymous with *Paanpoi.*

Paanpoi at Parali village, Satara district.

Many of these structures are located in various places in Satara district where there are also rivers and ponds. A similar structure has been spotted next to the Puratan Shiv Mandir (17.6651341,73.9125418) in Parli village, Satara district [5],[6].

Parali village is located close to the banks of Urmodi river and dam, 1km north of Sajjangad Fort and pilgrimage site, 14 km west of Satara and 135 km south of Pune. The village serves as one of the starting points for the trek to Sajjangad Fort. Located a short distance north-west of the village, the ancient Shiv Mandir (17.6651341,73.9125418) site stands in isolation (Figure 15). There are two main temples at the site, both built in a Hemadpanti style.In front of the two south-facing temples are the remains of a number of structures. An elaborately carved *Deepstambha* (lamp post) or potentially a Victory Pillar on a well carved platform look to be reused materials from perhaps the southern temple. Forming an east-west line in front of the main temple entrance are a set of north-facing hero and sati stones. To the north are a few further small shrines, and a 40m square tank which is overgrown now. Nearby is also a beautifully carved Ganesha idol sitting in the open air, two Nandis (one headless now) and a crudely constructed pavilion (Figure 16) which appears like the Paanpoi at Shirwal. However, there is no water pot inside this pavilion.

	
F15: Puratan Shiv mandir in Parali village, Satara Source: author	**F 16: Unknown structure at Parli village, Satara. Source: author**

It is not clear whether this crudely constructed pavilion is a *Paanpoi* or not because it is located next to the Urmodi river. Also, there is a tank (Kund) besides the ancient Shiv Mandir. The pavilion is located in between the temple and the Kund. Hence there is a possibility of this structure to be ruins of a Shiva temple.

***Paanpoi* at Dhawalgaon, Pusegaon Phaltan road, Satara district.**

A similar structure (17.8986324,74.3515785) was spotted at Dhawalgaon village on the Pusegaon Phaltan road, Satara district (Figure 17). It is located in a pasture (Figure 18). The stone water pot has disappeared.

5.8 **Sita Nhani, Gautala Autramghat sanctuary, Aurangabad district.**

The Sita Nhani (20.3418093,75.1432232) is located inside the Gautala Autramghat sanctuary in Aurangabad district of Maharashtra (figure 19). This sanctuary lies in the Satmala and Ajantha hill ranges of the Western Ghats.

**F17: Unknown structure at Dhawalgaon, district Pune.
Source: author**

**F18: Site surroundings of the unknown structure at Dhawalgaon, district Pune.
Source: author**

There are two stone pots partially buried in the plinth of the structure (figure 20). There is a junction called *'Paanpoi Phata*' on the road that connects Sita Nhani to Ghrishneshwar Jyotirlinga Temple and Kailas Temple, Ellora. The name suggests that there could have been a historic *Paanpoi* at this junction before the widening of national highway 52 i.e. Dhule Solapur road.

**F19: Sita Nhani, Aurangabad.
Source: Mayur Shelar**

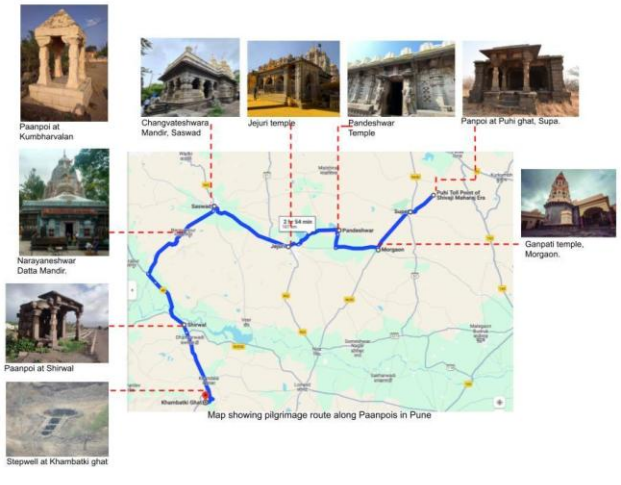
**F 20: Stone water pots at Sita Nhani, Aurangabad.
Source: Mayur Shelar**

Discussion

The water features on this walkway suggest that it must be of utmost significance (Figure 21). This route departs from Pandeshwar and travels via Jejuri, Kumbharvalan, Saswad Village, Narayaneshwar Temple and Shirwal. Further this path joins the Khambataki Ghat.

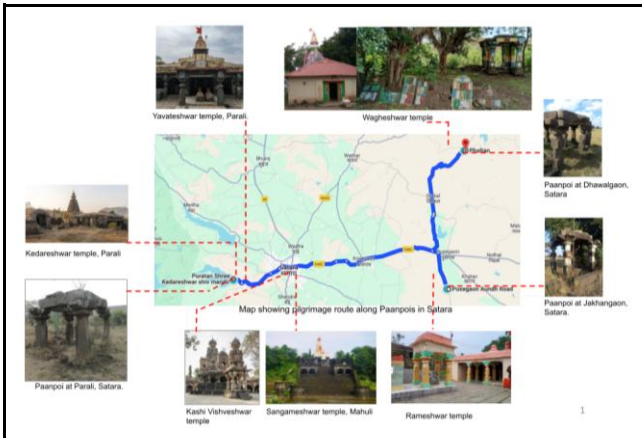
There is another route, which goes from Saswad to Kumbharvalan, Pandeshwar, Jejuri, Nira, Morgaon, Supe, and then from 'Puhi' Ghat to Solapur Road.The *Paanpoi* at Kumbharvalan village is between the *Paanpoi* at Shirwal and the Paanpoi in Puhi Ghat. Hence the Paanpoi at Kumbharvalan is of strategic importance.

Since there are places of pilgrimage on both these routes, the pilgrims, the people from the Sardar family, wherever they came from, would have been visitors of this Paanpoi.



F21: Map showing pilgrimage route along Paanpois in Pune. Source: author

The temples on the route from Parali village to Phaltan suggest that it must be a very popular pilgrimage route (Figure 22). This route departs from Parali village and travels via Mahuli Sangam, Koregaon, Pusegaon, Jakhangaon and Dhawalgaon. Further this path joins the Phaltan.



F22: Map showing pilgrimage route along Paanpois in Satara. Source: author

Conclusion

Paanpois were erected on the passenger, merchant and pilgrimage routes from long ago. The water here is distributed for charity. Knowing that there is no virtue like water, such water tanks were built. Devotees used to drink water at such places and move forward.

The seven *Paanpois* mapped in Pune, Satara and Shrigonda are located within a radius of 70 kms. The relative importance of this region as a probable pilgrimage route node during the period (13th to 18th century AD) appears quite obvious when one takes into consideration the presence of these seven *Paanpois*.

They are constructed in the Hemadpanthi style of architecture.

Due to the overall appearance of these ancient Paanpois, they are considered to be temples or samadhis (memorial) by local people. Ancient toll booth / toll plazas had a *Raanjan* (stone pot) to store the collected revenue. Hence the presence of identical stone pots in the *Paanpois* also makes one rethink whether it is an ancient toll booth over a trade route. Due to lack of archival data and documentation of these *Paanpoi*-like unknown structures in Satara and Aurangabad, it is still not understood whether they are temples or memorials or toll booths.

The mapped *Paanpois* are neither listed as graded heritage structures nor are they protected by the Archaeological Survey of India. These *Paanpois* are lying in a dilapidated state. This historical heritage is now on the verge of extinction due to road widening and age of the structure. There is a need for conservation of *Paanpois* to preserve the ancient practice of this charitable system of providing drinking water to passersby. Further studies like mapping, documentation and exploration of more of these structures is necessary to conserve them.

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